THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY

With which is incorporated the Institution of Aeronautical Engineers

A CLASSIFIED LIST OF ARTICLES—1917-1928

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Recent Model Experiments in Aerodynamics	E. G. Richardson, M.Sc., Ph.D.	September, 1927
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NOTICES

Elections

The following members were elected at a meeting of Council held on December 6th :—

Fellows.—Major F. A. Bumpus and Captain F. L. M. Boothby, R.N. (Ret.), re-elected.

Associate Fellows.—Flight-Lieut. C. H. Awcock, O.B.E., Wing Commander H. Blackburn, M.C., A.F.C., Mr. J. C. Dodds, Mr. E. J. Fearn and Mr. K. Robertson.

Associates.—Mr. F. W. Ashpole, Mr. H. J. Leech and Mr. D. R. L. Railton.

Students.—Mr. J. E. Blum, Mr. G. B. Fenton, Mr. E. Finn and Mr. R. A. W. Tilley.

Member.—Mr. A. N. D. Smith.

Lecture Cancelled

Owing to severe illness Major H. N. Wylie will not be able to give his lecture on February 2nd on "The Design and Production of Steel Aircraft." It is hoped that arrangements can be made for the delivery of the lecture later in the Session.

Endowment Fund

The attention of all members is drawn to the Endowment Fund, which now stands at £597 2s. The object of the Fund is to form a source of income which is independent of fluctuations of the subscriptions and grants from various bodies, so that the Society can proceed steadily with its work of disseminating as widely as possible all technical information, of advancing technical progress in every way, and of stimulating an interest in aeronautics by an increasing number of lectures and discussions. On October 23rd, 1926, the Duke of York wrote to the President, Air Vice-Marshal Sir William Sefton Brancker, and said :

"I am proud to feel that the Prince of Wales and I share between us the honour of being Patrons of the oldest aeronautical body in the world. The work of the Society is growing constantly in magnitude and importance. Its position can be maintained and improved only if all those connected either directly or indirectly with aeronautics give their fullest support. The munificent gift from the Guggenheim Trust Fund of the U.S.A. will in a measure enable the scope of the Society's activities to be widened, and I hope that those public-spirited persons or bodies who have in the past done so much to help forward our other great societies will give assistance so that a substantial Endowment Fund may be established."

The importance of increasing the Endowment Fund (the interest only of which can be used for furthering the objects of the Society) cannot be over-

exaggerated, and it is hoped that all members will bear the Fund constantly in mind. All contributions, which will be acknowledged in the Journal, should be sent to the Secretary and marked "Endowment Fund."

The Council wish gratefully to acknowledge a contribution of £20 to the Fund from the President, Sir W. Sefton Brancker. It is hoped that this contribution will stimulate others to contribute to the Fund within their means.

Branch Notes

Branch Notices appear on pages 69-88.

International Aeronautical Exhibition, Berlin, 1928

Full particulars of the forthcoming International Aeronautical Exhibition, which is to be held in Berlin from October 7th to 28th, 1928, may be obtained from the Society's offices.

Library Catalogue

The first printed catalogue of the books in the Society's Library is now on sale, price 5/- a copy, at the Society's offices.

List of Articles Published in the Journal

In each copy of the January issue of the Journal has been inserted loosely a copy of a leaflet giving the more important articles which have been published in the Journal since 1917.

Society of Motor Manufacturers and Traders, Ltd.

The Council have received with much gratification the following letter from the Secretary of the Society of Motor Manufacturers and Traders Ltd. :—

> ". . . [The Council] asked me to say how delighted they were that the negotiations which took place under the Chairmanship of Sir George Beharrell have ended so successfully.
>
> The Council have authorised a contribution to the funds of the joint organisation of £250 per annum, which they hope it may be possible for them to continue for a period of three years."

The Council wish to place on record their grateful thanks for the generous action of the Society of Motor Manufacturers and Traders Ltd.

Library

The following books have been recently received and placed on the Library shelves :—

Physics in Industry. Lectures delivered before the Institute of Physics, Vols. I., II., III. and V.
Modern Aircraft, by V. W. Pagé.
Measurement of Air Flow, by E. Ower.
Jane's All the World's Aircraft.
A.P.1278. Jupiter Series VI. Aero Engine.
A.P.1287. Lynx IV. Aero Engine.
Aeronautical Research Committee. Reports and Memoranda—
No. 1072. Characteristics of Certain Aerofoil Sections for Infinite Aspect Ratio, by A. S. Hartshorn.
No. 1092. A Distant Reading Instrument for the Measurement of Small Displacements, by E. F. Relf and L. F. G. Simmons.
No. 1102. Undercooling of Some Aluminium Alloys, by M. L. V. Gayler.

Major B. F. S. Baden-Powell

In the October Journal reference was made to an historic picture by the Chevalier Charles de Lorimier, which is now hanging in the Secretary's room. It was omitted to state in the description of this picture that at the time Major F. S. Baden-Powell bought the picture he very generously presented it to the Society, adding one more act to the many which he has done in the past on its behalf.

Review

Internationale Studiengesellschaft zur Erforschung der Arktis mit dem Luftschiff, reviewed in the last issue of the JOURNAL, is published by Justus Perthes of Gotha, price 5 dollars.

The paper by Nikuradse, reviewed in the December JOURNAL, is published by the VDI—Verlag, Berlin.

Correction

For $v=ay^{\frac{1}{2}}$ on page 1170 of the December issue read $v=ay^{1/7}$.

Forthcoming Arrangements

Thursday, January 5th, 6.30 p.m.—Mr. A. Fage, A.R.C.Sc., Fellow, "Some Recent Experiments on Fluid Motion."

Thursday, January 19th, 6.30 p.m.—Major W. S. Tucker, D.Sc., A.M.I.E.E., "The Problem of Noise in Civil Aircraft and the Possibilities of its Elimination."

Thursday, January 26th, 6.30 p.m.—Joint Lecture on "Schneider Trophy Machine Design," by Mr. R. J. Mitchell, Mr. P. A. Ralli and Captain G. S. Wilkinson.

Tuesday, February 7th, 6.30 p.m.—Wing Commander I. G. V. Fowler, A.F.C., "The Maintenance and Repair of Aero Engines." Joint Meeting with the Institution of Automobile Engineers.

J. LAURENCE PRITCHARD, *Secretary.*

SPECIAL GENERAL MEETING

A Special General Meeting of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, was held in the Library of the Society on Thursday, December 29th, 1927, to consider the proposed new Rules.

The following were present at the meeting:—

Colonel the Master of Sempill in the chair.

Capt. P. D. Acland.
Mr. Patrick Alexander.
Flight Lieut. R. E. H. Allen.
Colonel N. Belaiew.
Mr. R. M. Balston.
Capt. F. L. M. Boothby.
Mr. M. L. Bramson.
Mr. Griffith Brewer.
Mr. S. Camm.
Colonel Cave-Browne-Cave.
Mr. C. R. Fairey.
Mr. J. D. Frier.
Mr. W. E. Gray.
Mr. J. E. Hodgson.
Mr. C. D. Holland.
Mr. S. Hooper.
Mr. N. J. Hulbert.
Mr. H. B. Irving.
Capt. A. G. Lamplugh.
Mr. M. Langley.
Major A. R. Low.
Lieut.-Col. M. O'Gorman.
Mr. J. S. L. Oswald.
Mr. Handley Page.
Mr. J. Laurence Pritchard.
Mr. F. L. Richards.
Capt. W. H. Sayers.
Dr. A. P. Thurston.
Sir Vyell Vyvyan.
Dr. H. C. Watts.
Mr. H. E. Wimperis.
Mr. L. A. Wingfield.

Before the Secretary read the notice convening the meeting a vote of condolence was passed to the relatives of the late Sir Mackenzie Chalmers.

The Chairman briefly outlined the objects of the meeting and of the formation of the Rules Committee, under the chairmanship of Lieutenant-Colonel Mervyn O'Gorman. He explained that the rules had been modelled on those of the Institution of Civil Engineers, had been unanimously arrived at by the Rules Committee and approved by the Council. Lieutenant-Colonel O'Gorman explained the work of the Committee at some length. He pointed out first of all that the composition of the Committee called for two members from each body and a Chairman to be appointed by themselves. He was happy to say, and considered it a point of considerable importance, that every proposed new Rule, as now laid before them, had been agreed to unanimously by the representatives of both bodies and on not a single question had any one on the Committee been over ruled or compelled to ask for a vote. This appeared to him so satisfactory that he wanted it placed on record. As the Chairman had pointed out, the new Rules were based very closely on those of the Institution of Civil Engineers whose rules had stood the test of time and were undoubtedly the best of their kind. Each rule had not only been considered in the light of its bearing on other rules, but with an eye to the future of the Society. There had been a number of comments, mostly friendly ones, on the retention of so many grades in the amalgamated Society. He was in thorough agreement with that attitude, but it must be remembered that the Committee were bound by the terms of the Beharrell Report, which had been passed by General Meetings of both bodies. He thought it quite possible in the future that some of the grades might be conveniently dropped, but that was a matter for the future, and it was dangerous to prophesy what would happen. One advantage of the new Rules

was that they had considerably tightened up the definitions of each grade and, in his opinion, the status of the grades would benefit considerably thereby in the future.

The Rules now before them had not only been carefully considered by the Committee who had spent many months on their preparation, but they had been unanimously approved by the Council and, furthermore, had been revised not only by the Honorary Solicitors of the Society and the Institution but by an independent conveyancing solicitor, so that he felt the Rules had been very thoroughly digested, as it were, before they were presented for approval. He hoped, therefore, the Meeting would pass them, in principle at any rate, and only make such minor amendments as they thought fit.

The Chairman then proposed and Mr. L. Wingfield seconded, that, with certain amendments, the Rules should be accepted in principle.

It was agreed that the title of Founder Member should be retained, that the short title of the amalgamated Society be R.Ae.S.I., and that a number of other amendments should be incorporated in the draft Rules as originally circulated.

Several members asked if a double subscription was payable for those who belonged to two grades, a definite promise having been given at the general meeting of the Institution of Aeronautical Engineers, at which the Beharrell Report was adopted, that a double subscription would not be payable.

Mr. L. A. Wingfield, who was present at the general meeting in question, and was also a member of the Rules Committee, explained that he understood that no person would be liable to two subscriptions. Under the new Rules only a single subscription was asked for, but a person who wished to use two designations would be required to pay the subscription of the higher grade and an annual registration fee of one guinea. He had no doubt that Rule 65, which referred to the subscription payable by a person who wished to use two designations, was drafted in the spirit of the promise made at the General Meeting of the Institution. The extra annual guinea was in the nature of a registration fee, and no member need use both titles to which he had a right, unless he wished. The Society, by waiving any right to charge a double subscription, would actually lose a certain sum of money, and this would only partly be made up by the registration fee.

Captain Sayers stated that he was at the meeting in question and he agreed that a promise was made that two subscriptions should not be charged. He thought the new Rules were quite clear on the point. Those who were entitled to belong to two grades had the privileges and designations of both grades for half the amount of both subscriptions. As he understood it, the promise was one that the double subscription would not be expected from individuals who happened to be joint members, and there was nothing in the promise, nor implied in it, that there would not be some variation in the subscriptions as they then existed. He was fully satisfied with the new Rule governing the point which had been raised.

The Chairman then moved and Lieut.-Colonel M. O'Gorman seconded the following resolution:—"The Secretary be instructed to incorporate in the Rules, which have been agreed in principle, the following various alterations: (1) Those on the Hectograph sheets circulated at the meeting; (2) the modifications moved be agreed to by the meeting and to get these printed. That these be circulated subject only to editing corrections being introduced as required by the Secretary."

The meeting passed a resolution that the new Rules should come into force on January 2nd, 1928.

PROCEEDINGS

Second Meeting, First Half, 63rd Session

The Second Meeting of the Sixty-Third Session of the Royal Aeronautical Society with which is incorporated the Institution of Aeronautical Engineers was held in the Theatre of the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on Thursday, October 13th, 1927, when Squadron Leader T. H. England, D.S.C., A.F.C., read his paper on "The Practical Side of the Performance Testing of Aircraft." Colonel the Master of Sempill (Chairman of the Society) was in the chair.

Colonel the Master of Sempill: The preceding lectures given before the Society on the subject of performance testing were given by Colonel Tizard, Major Barlow and Mr. Capon. I am glad to say that Colonel Tizard is here to-night and has promised to open the discussion.

Squadron-Leader England is well known to you, as also, of course, his brother, Gordon England, who was one of the first to take up flying in this country. Our lecturer commenced his aeronautical career some time before the war, and was associated with Mr. Howard-Flanders, who was, as you know, one of the Founder Members of the Institution of Aeronautical Engineers. During Squadron-Leader England's service in the Royal Air Force, which lasted up to a few months ago, he gained considerable experience not only in this country but in many other parts of the Empire. He is eminently fitted to give us a paper on "The Practical Side of the Performance Testing of Aircraft," having been for some years in command of the Testing Squadron at Martlesham Heath. He now occupies a position with Messrs. Handley Page, and I think it is giving no secret away to say that since he went to that firm the slot has been greatly improved in so far as its practical application to aircraft is concerned.

I now have pleasure in calling upon Squadron-Leader England to give us his paper.

THE PRACTICAL SIDE OF PERFORMANCE TESTING OF AIRCRAFT

BY SQUADRON-LEADER T. H. ENGLAND, D.S.C., A.F.C.

Some six months ago I was requested by your Chairman to deliver a lecture on the Practical Side of Performance Testing of Aircraft, and acceded to his request, because at that time I considered it a comparatively simple matter. Now, however, being a member of the aircraft industry, and in consequence having an altered outlook, I find it a most difficult task—my friendly enemies have become my friends and vice-versa. Consequently I have endeavoured to write my paper sitting on the fence.

In dealing with the growth of the practical side of performance testing, as opposed to the scientific side, on which Flight Lieut. Capon has already given a lecture, it would be as well to make a brief survey of the methods which were used before the Great War, and of those now in force, at the Experimental Testing Establishments.

In the early days of flying—I speak now of the years 1912 to 1915—most of the testing was carried out at Farnborough. Subsequently a testing squadron was

situated at the C.F.S. at Upavon. As the work increased and Upavon was needed as a school, it was found, soon after the commencement of the war, that it was necessary to transfer the testing squadron to a unit where it would be unencumbered by other restrictions. It was in this way that Martlesham Heath was opened. The success of that establishment from its commencement was due to Colonel W. T. Tizard.

The object of performance testing in those days was to ascertain how high and how fast a certain machine would fly. Little attention was devoted to the accuracy in carrying out type tests in regard to the all-up weight at which the aircraft flew, and it was the custom merely to fill up the fuel tanks to their maximum capacity. Attention was not directed to the weight of the pilot or, if carried, the passenger, or any military equipment, which admittedly in those days was exceedingly meagre. Furthermore, the instruments, like the aeroplanes, were not as reliable as those which we are now fortunate to possess. The question of calibration of instruments or airscrew was unheard of.

Speed tests were carried out over a speed course of approximately three-quarters of a mile in length, having two timing boxes at either end. These were electrically connected, so that when the aeroplane, which flew as close to the ground as possible, passed a box the timekeeper pressed his stopwatch. Climbs were carried out by the pilot, who had a small pocket recording barograph, so that he merely flew until the machine would not ascend any higher. Partial climbs to determine the best climbing speeds, of course, were not done, neither were corrections made for temperature, etc. The above is a very sketchy outline of the method employed in carrying out tests. It will be appreciated that, although crude, these tests were more of a practical than scientific value. Nevertheless, great credit is due to those who carried out the tests, considering that it is only after years of careful attention to detail, with every scientific apparatus at their disposal, that the Testing Establishments have been able to reduce their errors to less than one per cent.

The objects in carrying out performance testing are :—

1. To obtain data in regard to the performance of an aircraft, such as rate of climb, speed at various altitudes, stability, controllability, landing speed, get-off and landing run.
2. To find out structural defects.
3. To test the suitability of the aircraft for the purpose for which it has been designed.
4. To frame a report to which the staff officer can turn as a means of reference.
5. To collect sufficient data to enable the designer to check up his design figures.

The methods used by the Testing Establishments are continuously being modified, and likewise the methods of executing the various tests. When a new method is devised, it is not immediately adopted for standard type tests, but applied and experience gained with it in checking results which are already known. When the system has been perfected and found to be more advantageous than the system used hitherto, it is then, after due consideration, made standard. If some of the tests which I am about to describe have been revised since my departure from Martlesham Heath, it is because some better method has been evolved, and I hope that any misstatements which I may make will be corrected.

Type trials embrace no less than ten special tests and are preceded by a weights and C.G. investigation and calibration of the airscrew. It may be said that there are three different stages through which an aircraft passes whilst at a testing establishment. These can be divided as follows :—

1. The weighing, loading and C. of G. investigation.
2. Handling trials.
3. Performance tests.
4. Preparation of report.

A contractor sends his aircraft, which has either been built to an Air Ministry contract or is a private venture. In the latter case the designer may, if the aeroplane is designed to or for an A.M. specification, get them to test it at their expense; if the aircraft does not interest the A.M. the contractor will be required to pay a nominal fee for testing.

On arrival of the aircraft it is allocated to a "Flight," who check it over to see that so far as equipment and other items go, it complies with an official document known as the "Appendix A." The aircraft is then drained of fuel, oil and water, and weighed, filled afresh with fuel and reweighed.

During the weights investigation, manufacturers' instruments, such as air speed, r.p.m. and altimeter are removed and special test instruments substituted, the calibration of which is already known.

In passing, I might mention that it is easier to get an aeroplane to agree with the manufacturer's figures in climb and speeds than it is so far as weights are concerned. Although an aircraft may have flown only half-an-hour, or less than 100 miles, it somehow or other collects from the upper heavens an odd 100 lbs. or so. It may be that the air conditions prevailing round Martlesham are less buoyant than those round the manufacturer's scales. Once the loads have been decided upon, a weight sheet is got out and the aircraft is loaded up in accordance with the weight sheet and the C. of G. taken. Here again may I remind manufacturers that it would repay them to take the C. of G. of their aircraft with the full equipment distributed according to the lay-out of the machine in accordance with the Appendix A, and not merely put so many lbs. in the various seats regardless of where the equipment will be placed in service.

Once the position of the C. of G. has been clearly defined (or should it be ascertained that the limits are beyond those stipulated by the Air Ministry and necessary approval obtained for the aircraft to be flown) the load in the aircraft is reduced to a light load and flown by two or three pilots who will be responsible for its air tests, after which it is loaded up according to the required load and is ready for performance tests.

It is as well to mention that during the weights investigation the manufacturer's instruments such as airspeed, revolution counter and altimeter are removed and special test instruments substituted, the calibration of which is already known.

Full performance testing embodies the following:—Partial climbs, climbs, speeds, speed course, stalling speeds, landing speeds, longitudinal stability, landing and take-off trials, radiator tests, petrol consumption. In addition, there are special tests such as spinning and stability.

Before detailing the tests, a few remarks on the part played by the pilot and the equipment he uses may be of interest. When the pilot's goggles are pulled down over his eyes he is completely covered. The abundancy of electrical equipment is necessary to provide heating for the pilot's eyes, hands, body and feet. Oxygen is used to assist the breathing when tests are being conducted at altitudes above 20,000 ft. Strapped on to his right leg is a test card and on to his left leg an aneroid. The test card is for jotting down the figures he obtains and the aneroid is carried in addition to that fitted on the dashboard; the reason for this is that, invariably, there is vibration on the dashboard, and as this instrument is super-sensitive a pilot cannot obtain accurate readings should the needle be vibrating. In addition to the above the pilot has a stopwatch which is used for checking rate of climb, etc., and a control for regulating the heat of his goggles.

The adequate clothing of a pilot is one which has not received sufficient attention. Recently various methods and new flying suits have been tried, but in my opinion they lack the essential feature in that they take too long to get into and are too cumbersome. I see no reason why a flying suit containing all the electrical equipment, with the goggles, helmet, gloves and feet cannot be made in one piece, and to this attached the parachute; the first essential being that the suit be light, otherwise it fatigues the pilot or observer.

Partial Climbs

The object of these partials is to determine the correct climbing speeds of the aircraft, in addition to which valuable data may be obtained respecting air-screw and engine characteristics, fuel consumption and maximum range. In carrying out these tests, accuracy is of the first importance as the complete performance of the aircraft may be deduced from the results obtained.

Normally the mean heights of the tests will be approximately at one-fifth, two-fifths, three-fifths and four-fifths of the service ceiling. In cases where full throttle is not permitted until a certain height is reached, the above figures may, of necessity, be modified. The order of the tests will be partials at one-fifth, two-fifths and three-fifths of the service ceiling. For these no barograph is carried. The final set of partials is just a climb to four-fifths of the service ceiling at climbing speeds previously determined. On reaching this altitude a partial is carried out. A barograph is carried in this instance. Level speeds are carried out on the way down. Partial climbs are carried out at full throttle and at the same A.S.I. at all heights. The total range of airspeeds is that necessary for the last set of partials. At this height the airspeeds used will vary from 5 m.p.h. above stalling speed to 10 m.p.h. above full throttle level speed. The height range used should be such that under two minutes is taken over each partial and not less than one minute. In case the engine is exceeding its maximum permissible r.p.m., the last partial, which is a descent, has to be carried out with a suitable throttle setting.

Readings are taken of heights at the beginning and end, also of time taken, of air temperatures, of mean A.S.I. and r.p.m., and of the extent to which the altitude control is used.

The correct use of altitude or, correctly speaking, mixture control is found at a given A.S.I. by giving A.C. until the r.p.m. shows a tendency to decrease, when the A.C. is diminished until the r.p.m. shows its maximum again.

In cases where the aircraft is fitted with flaps, partials have to be carried out with different flap settings, and this is consequently a very lengthy test.

Partial climbs are usually (particularly the lowest) carried out in the early morning when the air conditions are favourable and vertical currents are minimum.

Climbs

The object in carrying out a climb to ceiling—ceiling being defined where the rate of climb has reached 100ft. per minute—is to ascertain if the deductions made from the partial climbs are substantiated.

For a climb to ceiling a pilot is given an airspeed which varies according to different altitudes through which he passes. As the aircraft passes through each 1,000ft. the pilot has to record on his test card the following:—Time (according to stopwatch), r.p.m., strut thermometer readings, water and oil temperatures, and amount of altitude control used. When the ceiling is reached the pilot makes his final entry in regard to the climbs on his test card.

Speeds

These tests are to determine the level speed at a known height and are therefore carried out after a climb to ceiling has been completed.

Having reached the service ceiling the aircraft is flown level by means of a statoscope and kept on its course for at least three minutes, at the conclusion of which the pilot enters on his test card the height at which the speed was commenced and finished, air temperature, A.S.I., r.p.m., altitude control and oil and water temperatures.

Barographs are always carried for climbs and speeds. This enables the pilot's test card to be checked up, and shows if there are any peculiar features either in the climb or the speed.

Speed Course

Object.—Speed course is a method used for checking the position error of an aircraft and also for the ground speed. In order to obtain accuracy the speed course runs are carried out with the wheels of the aircraft not less than 10ft. from the ground and a wind speed of less that 5 m.p.h. As this test, especially in regard to high-speed aircraft, involves the pilot's full attention, it is only possible for him to obtain two readings, namely:—A.S.I. and r.p.m.

The speed course at Martlesham is a mile long with about an additional quarter of a mile at each end for entry and exit. An aircraft is electrically timed over the course by two observers, one at each end of the measured course.

The apparatus consists, essentially, of a tape machine with two recording pens operated by electromagnets. The tape is passed beneath the recording pens by the action of a small electric motor which, by the use of a variable resistance, may be made to move the tape at a rate varying from 0.5 cm. to 3 cms. per second. Thus there is given a timing tape of reasonable length which, of course, varies according to the speed being measured.

One recording pen is operated by the action of a calibrated pendulum, and from this a contact passes through a small globule of mercury at its lowest point, thus momentarily closing the electrical circuit to which the recording pen electro-magnet is connected. This pen imprints a straight line on the tape punctuated by marks which represent one section interval of time between any two adjacent points. The other pen is operated by an electromagnet which forms a part of a circuit connected with a tripping mechanism attached to the two cameras which are operated one at each end of the speed course. This second recording pen imprints a straight line on the tape, opposite to the seconds line, punctuated by marks made when the circuit is closed by the tripping mechanism of the cameras.

The cameras, one at each end of the course, are mounted on pivots so that they may be revolved in the horizontal plane. Each camera is fitted with a cam gear which operates a trip mechanism at the moment the optical axis of the camera passes the perpendicular line at the end of the course. The trip mechanism operates at the same time the shutter of the camera and the contacts of the circuit of the second recording pen.

The speed course is, normally, used in the early morning in order to take advantage of the better weather conditions which usually exist at this period of the day. The aircraft is flown at a number of speeds varying from about 5 m.p.h. above stalling to the maximum speed of which the aircraft is capable, each speed being carried out twice up and twice down the course. The records which are obtained are the speed tapes marked with the timing lines and two photographs for each run, one from each end of the course. These photographs are used to correct the length of the speed course in case either operator has not traversed the camera with sufficient accuracy to time the aircraft exactly at the moment of passing the perpendicular line of the end of the course.

A somewhat similar method is used at Felixstowe and a description of the apparatus may be of interest.

The speed course is three kilometres in length. Alternate methods of timing are available, namely wireless and camera gun. This permits of a breakdown of one method, whilst still having a reasonable chance of carrying on with the other.

Two observation posts with wireless transmitters and receivers are situated at each end. Ground signals are put out and connection is thus made with the aircraft, which proceeds to fly across the speed course when the "carry on" signal is given. As the aircraft passes the commencing site the observer presses the buzzer-key which from a wireless relay clicks one of three pens operating on the chronograph tape at the other end. A thirty seconds' pendulum clock at this end operates a second pen which is ticking off seconds on the same tape. Passing the sights at the end observation post, the other observer presses his buzzer-key and a third pen is brought into action with the tape. A record is thus achieved, showing a pen mark at start and finish with second marks run along the whole length of tape.

Wind speed and direction are separately measured along the course. Fitfulness in velocity and direction are probably responsible for the major element of inaccuracy, but it should be mentioned that the total error does not appear to exceed one per cent.

Camera guns at each end of the course are employed as a check method and also as a second line of defence in case of wireless trouble such as pen response to the kick of spark jambing, acute atmospherics, etc. Here, it is just a question of each gun being trained on the aircraft as it passes across the sights. The guns can traverse up and down but not laterally, as they are fixed to line up with the base line of the speed course sights. A stopwatch is incorporated in each gun and these are synchronised beforehand.

The films show an image of the aircraft passing across the sights and a "picture" of the stopwatch face, corresponding to every position of the aircraft relative to the sights. Thus comparison between the times shown at each end of the course can be made and the speed thereby deduced.

This method is in itself quite satisfactory, but again cannot be entirely relied on as it is possible that the mechanism may jamb or the operator may be hard put to it to "capture" the aircraft—restricted, as he is, to upward traversing only.

Stalling Speeds

The object of this test is to ascertain the stalling speed. The engine is fully throttled and the aircraft allowed to glide for at least one minute at the slowest possible speed. The maximum speed during that minute with the stick hard back is considered to be the stalling speed. Stalling speed from level flight (cruising) is carried out in a similar manner, being the highest speed recorded in level flight of at least one minute's duration, the level flight being determined by the use of a statoscope. The throttle position for cruising speed is found by the aircraft being flown at full speed at a given height and then throttled back to full speed less one-tenth. The throttle setting required for this is the setting for the test. A self-recording A.S.I. is used whilst carrying out these tests, and a suspended static for all but single-seaters.

Landing Speeds

The object of this test is to ascertain the speed at which the aircraft touches the ground and is similar to the stalling speed, for the landing speed is taken immediately prior to the sudden drop of speed which occurs when the wheels touch the ground. It will be appreciated that this test is extremely difficult to do in the case of single-seater aircraft, but where an observer can be taken, he takes the speed whilst the pilot concentrates on the handling of the machine. As a rule a recording airspeed indicator is used for the tests.

Longitudinal Stability

The object of this is to find out if the aircraft has any degree of stability. As in the previous tests, a recording A.S.I. operated by a remote control is fitted to the aircraft. The aircraft is first trimmed so that it may be flown, hands off, or alternatively, if unstable, so that there is no force required on the control column. When a condition of steady flight has been reached, the mechanism of the recording A.S.I. is started and about twenty seconds later the speed is either increased or decreased by some 10 m.p.h. by means of the elevator control. The control is then abandoned and the aircraft allowed to return to its original trim in a series of oscillations, or should the machine be unstable it will diverge still further. The recording A.S.I. is allowed to run for approximately one minute after the aircraft has apparently regained its original trim.

These tests are normally carried out at altitudes of about 4,000ft. in order that the aircraft may be given every opportunity of regaining its original trim without undue concern on the part of the pilot. Longitudinal stability tests are carried out at maximum speed, minimum speed, slow speed (near stalling speed) and best gliding speed, with engine off. The pilot has to record the r.p.m., and if flaps are fitted, their angle.

Landing and Take-Off Tests

The object of these tests is to ascertain the length of run required for landing and taking off. The landing and take-off trials, more popularly known as " stick and unstick," are designed primarily to ascertain the smallest space in and from which an average pilot could make a reasonable landing and exit. These trials are confined to aircraft other than those of the high-performance single-seater fighter type.

" Stick and Unstick " trials are carried out on favourable days when the wind velocity is reasonably low; in the case of military aircraft, wind velocities up to about 10 m.p.h. may be allowed in cases of necessity, but trials of aircraft intended for civil use must be done in wind velocities which do not greatly exceed 5 m.p.h.

From the lay-out shown it will be observed that two flags are set out, in the direction of the wind, at an interval depending upon the type and climbing ability of the aircraft, the object being to ensure that the aircraft passes over an imaginary screen at the end of the run at a reasonable height, say twenty to sixty feet. At the end of the run two posts are set up perpendicularly to the wind direction and one hundred feet apart with the central track flag midway between them. These posts, surmounted by arrows, serve to indicate an imaginary screen at the end of the run and also serve as a scale for end-on photographs which are taken during the tests.

Two cameras are employed, one end on and the other perpendicular to the course, as shown; the cameras are operated simultaneously by an observer, who depresses a key when the aircraft passes the line of the imaginary screen. The photographs, taken by the camera in prolongation of the track, are used to scale off the height of the wheels of the aircraft above the ground level, and the photographs taken by the camera placed perpendicularly to the track, are used so that incorrectly taken end-on photographs may be discarded.

One set of " Stick and Unstick " trials consists of at least six successful runs in order that a reasonable average may be obtained.

In the case of civil aircraft the difference of level of the ends of the track have to be taken into consideration and this is done in the ordinary way by means of the normal field level and staff.

The methods adopted for seaplanes are as follows:—

The older methods relied on a water-speed meter carried on the aircraft, the reliability of which was doubtful and the results obtained very inconsistent.

It was natural that attention should be given to methods of outside observation and as a result the bearing plate method has been developed and has given excellent results.

The apparatus consists of two bearing plates situated some 900 feet apart which are electrically connected in series. At a point in the circuit a battery is inserted and the circuit is momentarily completed every second by means of a pendulum and mercury contact. On each bearing plate a metal arm is mounted and, pivoted at the bearing plate centre, carries sights and a pen which marks off second intervals on the bearing plate surface. This pen is actuated by an electromagnet responding to the seconds pendulum make and break. A master switch in the circuit, near one of the observation posts, is used to throw in the mechanism when the aircraft gets into position.

Range of Utility

This apparatus can be used for the determination of water speeds and the distance, speed and acceleration during landing and take-off runs, also air speeds of aircraft flying slowly close to the water level.

Method of Use

Operation proceeds as follows:—

Observers at each end of the course continuously train their sights on the aircraft. The metal arm holding the sights is thus traversed across the paper surface of the bearing plate. The seconds pen—mounted on the same metal arm—thus records the angular position of the aircraft relative to each observation post at second intervals.

In the case of take-offs and landings, the circuit is closed and broken by an observer at the master switch at the precise moment when the aircraft commences and finishes its run. On each paper record the seconds pen has plotted an equal number of marks, and it is, consequently, an easy matter to correlate the angular position of the aircraft at specified times and graphically to deduce the required results in the form of distances flown, speeds, acceleration, etc.

Radiator Tests

These tests obviously only apply to aircraft having a water-cooled engine, and are carried out in order to ascertain the suitability of the cooling system of the engine. Three tests are required under this heading, namely:—

(*a*) Flight Test.
(*b*) Ground Flow Test.
(*c*) Vapour Separation Test.

In regard to (*a*) the engine is run up on the ground in the normal manner and the aircraft, when ready, takes off. The outlet thermometer may be reading 75° with a latitude of 5°. On taking off, the radiator shutters are kept fully open and remain in this state until a climb to ceiling is completed.

In the event of the shutters having to be adjusted on account of undue cooling leading to misfiring, the effect of the test will cease when the shutters are altered. The records taken during the flight test are:—

1. R.P.M.
2. Aneroid height.

3. Inlet and outlet temperatures.
4. Strut thermometer temperatures.
5. A.S.I.
6. Stop watch times.
7. Ground readings at take-off for temperatures.

As far as practicable these readings are taken at over 1000 ft. on the aneroid, or in the event of fast climbing aircraft, at the shortest interval possible.

Vapour Separation Test

Arrangements of a system of tubing for catching and measuring the water which will be ejected from the overflow while the test is in progress has first of all to be made.

The radiators are filled and the engine run up at 75° temperature at normal ground r.p.m. with the shutters closed. The run up is continued until boiling point is reached. After this has occurred for 30 seconds the shutters are then opened to their fullest extent and the r.p.m. maintained until boiling ceases. The information required is:—

a. Water in system before test (cold) galls.
b. Air space in system before test (cold) galls.
c. Air temperature during trials °C.
d. Time taken to boil from °C. mins.
e. R.P.M. during run up
f. Water lost during run up galls.
g. R.P.M. during boiling period
h. Water lost during 30 secs. boiling period galls.
i. Air space after trial (cold) galls.
j. Steam and spray not recovered galls.
k. Time from opening of shutters to cessation of water loss secs.
l. Radiator inlet temp. when water loss began °C.
m. ,, ,, ,, ,, ,, ceased °C.
n. ,, ,, ,, ,, begins to boil °C.
o. ,, outlet ,, ,, ,, ,, °C.

Petrol Consumption Tests

For some time past considerable difficulty has presented itself in regard to measuring adequately the fuel consumption at a given altitude. Numerous tests have been made with flow meters. These however have, in practice, been found to vary considerably in extreme temperatures. The only practical method, therefore, is to fill up the tank in the aircraft with a known quantity of petrol (if the aircraft has a fuel system which does not permit this being done, a small auxiliary tank is fitted). The aircraft is taken off the ground and climbed to a height, which height may be known as the operating height. On arrival at the height, the pilot flies at a given air speed or throttle setting, according to instructions. Having attained this he changes over his petrol from the main to the auxiliary tank and at the same time starts his stop watch. After flying for 20 or 30 minutes the petrol from the auxiliary is cut off and the stop watch stopped. The aircraft then descends, using the main fuel tanks for supply, and on reaching the ground the quantity of fuel left in the auxiliary tank is measured when the consumption is easily arrived at, in view of the time recorded by the stop watch.

Instruments

It may be of interest to record that the success in eliminating errors at

Martlesham is in no small way due to the attention and meticulous care devoted to instruments.

Flying Officer Faulkner, late of Martlesham, has written a very instructive report on temperature effects on instruments used in aircraft performance trials. He finds that serious errors have occurred through temperature effects on the instruments amounting to 120 ft./min. in rate of climb, and 1700 ft. in ceiling, whilst errors in maximum level speed may reach the figure of 14 m.p.h. near ceiling. All instruments used at Martlesham are now calibrated for temperature.

Having reviewed the different methods adopted in carrying out the tests, one is faced with the problem of the drawing up and framing the full report, as there are so many aspects to be considered; this necessitates a large and versatile staff. In considering the report, one has to refer to the reasons for carrying out performance testing, and these I have given in the early part of my lecture.

The report is some 32 pages in length and embraces all the technical details, in addition to criticisms on the detailed design of the aircraft and shows how the type requirements have been met.

Before concluding it would be as well to analyse the devious methods used at the Testing Establishments. Three questions therefore arise:—

(*a*) Do all the tests fulfil the requirements of both civil and military aircraft?

(*b*) As a result of a Testing Establishment having a number of highly experimental aircraft for test and much information accruing, is the broadest use made of this information?

(*c*) Does the 32-page Report contain all the information that is required from the learned professor to the staff officer or company director?

In dealing with the first question—do all the tests fulfil the requirements of both civil or military aircraft—one is of opinion that even the critic will admit that, from the academic and scientific point of view, the methods used are justified by the results. On the other hand, there are several tests which are not carried out, and which under the present system are impossible to undertake except after a considerable lapse of time.

A modern aircraft can complete its type tests in 20 hours' flying. Assuming that the manufacturer does five hours' preliminary flying, making 25 hours all told, the aircraft is sent away in an untried state, as experience has shown that modern aircraft give little trouble for the first 25 hours, but, as the hours increase, so do the defects, although possibly of a minor nature. Since, therefore, military and civil aircraft are expensive to operate, and manufacturers are not over-burdened with orders, it is not feasible for them to carry out the 150/200 hours' development flying that is required. This can be done in the following method without undue delay—there will, however, be some small additional expenses, but these will probably prove an ultimate saving. I refer to the method whereby two machines are built, both being identical and completed at the same time; one machine is sent for performance testing whilst the other goes to a service unit or development squadron; the function of the latter being to keep the machine more or less continuously in the air until the period of development flying has been accomplished. This system would have the added advantage of thoroughly trying out the machine, under all conditions, and in all weathers and circumstances, bearing in mind that type testing has to be restricted to favourable weather. Far from it do I wish to infer that no bad weather flying is done at the Testing Establishments.

After the two machines have completed their tests the manufacturer and the Service would be in a position to know what modifications were necessary

should the type be placed in production. At the present moment aircraft, soon after they are placed in production, have countless modifications incorporated, clearly demonstrating that not only are the officers who order the aircraft fully acquainted with what they need, but that the machine has not been properly tested.

Referring to (*b*)—is the broadest use made of the information which must accrue as a result of a Testing Establishment having a number of highly experimental aircraft for test. This information, if directed to the right quarters, would not only assist the designer in preventing him making small mistakes, but would ultimately assist the service and could with advantage be published and circulated to firms on the Air Ministry's list.

For instance, taking a small item, but one which is subject to very hard use, namely, the tail skid; there are certain types of tail skids which are known to be satisfactory and there are certain types of tail skids which are known to be unsatisfactory, yet manufacturers are still permitted to fit the unsatisfactory type. If a report could be circulated on the trend of design of tail skids, or some similar part of an aircraft, it would be of the greatest assistance to all concerned. Again, recently, in order to obtain a higher top speed certain manufacturers have increased their landing speed. I believe that there are a number of designers at the present moment who are of opinion that a landing speed in excess of 65 m.p.h. is not a feasible proposition. Without disclosing any information on this subject, a report dealing with the fact of high landing speed, and the ultimate increase in top speed, might prove most helpful. I have only given two isolated cases, but these are given with a view to show that there are very definite cases which deserve attention.

Regarding the last question—does the 32-page report contain all the information that is required from the learned professor to the staff offices or company director—the report has reached the stage where it is so full of information that by the time it has been read through it is difficult to extract immediately any particular data for which you may be looking. It is highly improbable, viewed from the point of view of the staff officer, in the case of military aircraft, or that of the company director, in the case of civil aircraft, whether they can elucidate sufficient information from the report for their needs. I suggest, therefore, that the reports would prove of real value if based on the assumption that two aircraft were being tested as outlined a little earlier on, the results of which should be consolidated into one report. This would materially assist all concerned, as it would be so full of information that there would be no doubt left in the mind of those who have to decide, in the event of the type being placed into production as to which is the better machine.

In conclusion, I should like to say that much of the information which I have given you to-night has been due to the kindness and generosity of certain officers and officials at the Air Ministry and Testing Establishments, in addition to one or two others, to all of whom I take this opportunity of giving my thanks.

Discussion

The Chairman: I should like to congratulate the lecturer on having given us so much information on an all important subject. It is obvious to us that in this country we do not under estimate the importance of the performance testing of aircraft. We have established an A1 standard at Martlesham and Felixstowe, and I think it is a standard that has not been reached by any other nation.

We have with us to-night Colonel Tizard, who has been more responsible than anyone else for the development of the testing methods in use to-day. He is therefore the most suitable person to open the discussion, and I have much pleasure in calling upon him to do so.

Colonel TIZARD: At the commencement of his paper, Squadron Leader England paid me a tribute that did me more than justice. I should like to take the opportunity of referring to the work of two men among many old colleagues who were concerned with the establishment of Martlesham Heath. At Martlesham and Upavon we were always fortunate in Commanding Officers, but my view is that Major (afterwards Wing Commander) Mills, who commanded the Experimental Flight at Upavon in 1916 and became the first Commanding Officer at Martlesham, was the first regular Flying Officer to realise completely that in this kind of work military organisation and discipline, all important though they are, must be made subservient to the main technical work of the establishment.

If it had not been for Major Mills's keenness, energy and hard work it would not have been possible to do what we did at Martlesham, and I am glad to be able to judge by Squadron Leader England's paper that the tradition, created largely by his example, has not been allowed to die. Major Mills was subsequently killed in France, and I know that his loss was a personal one to many.

The other man, who is still alive, is Mr. Dobson, a distinguished scientific man, now lecturer in meteorology at Oxford. He was the Chief Technical Officer of the Experimental Flight at Upavon, and to him was largely due the development of many of the flying instruments which were used in performance testing. I think I am right in saying that he was one of the first to realise the great importance of measuring fuel consumption accurately in flight, and that he designed the petrol flow meter which was actually in use in early days. It was through his initiative that the manufacture was taken up, and we used many of them with great success. Now, after the lapse of many years, it has not been possible to improve substantially on his design of flow meter, and for accuracy we are driven back to a 20 minutes' test by actual measurement of the petrol consumed. This certainly has the advantage of accuracy, but the disadvantage that the consumption can only be measured over a very limited range of speeds and other conditions. My own view is that the petrol consumption needs to be measured throughout the whole range of speeds and heights, and with as great care and accuracy in flying as possible. I should therefore be glad to hear what chance there is of developing a satisfactory instrument. I think we ought to look to Martlesham Heath to be able to give us standard results on what an aeroplane should consume in the air. We all know that consumption in flight in actual practice is much more than it ought to be, and I understand that something like £100,000 is wasted yearly, partly through lack of data on what correct fuel consumption in flight should be, and also because no efficient automatic altimeter control of consumption has yet been developed.

I should like to know whether Squadron Leader England in his flying experience at Martlesham Heath or elsewhere has ever observed any curious unexpected phenomena. Very often scientific advances are based on curious observations by men in touch with practical realities. At Martlesham Heath and Farnborough I found that skilled pilots and observers had experiences and noticed important things when flying that other people did not see or expect. I think it is a matter of importance to encourage flying officers to make observations other than routine observations even if they do not understand them. It is, of course, important that such observations should be correct. I remember the first time that I saw a machine spin, the eminent pilot in charge assured us that the air speed indicator had read backwards! It was not until a civilian "highbrow" at Farnborough had the temerity to spin a machine himself that we had accurate scientific information on the subject.

I congratulate Squadron Leader England very much on his valuable paper.

Flight Lieut. CAPON: There is one question I wish the lecturer had been

able to deal with more fully, and that is, performance testing from the pilot's point of view. The pilot has to do two things at once and do them both very well; he has to operate the controls with great delicacy of touch and at the same time take readings of instruments with great speed and precision.

During my two years at Martlesham as Chief Technical Officer several attempts were made to discover what the errors of the pilot were, *i.e.*, to separate his errors from the instrumental and other errors. There appeared to be little doubt that they were of the order of 1 per cent., an accuracy which must, I think, appear surprisingly good to anyone who understands the difficulties of the work. Test piloting is probably more an art than a science and no doubt Squadron Leader England would find it difficult to explain how so high an order of efficiency is achieved and still more difficult to give rules of thumb which might be of benefit to other test pilots.

As regards the question of petrol consumption, the situation has, I think, become much more hopeful in the course of the last few months. A petrol flow meter has been evolved which has given very promising results and, though the well known difficulties of the problem and previous experience with flow meters warn us to adopt a cautious optimism, it does appear probable that a sufficiently accurate flow meter will soon be available, leading, it is hoped, to the saving of a considerable part of the £100,000 referred to by the previous speaker. It should, I think, be pointed out that no other country, so far as I am aware, has yet produced a flow meter for use in the air which has been accepted as accurate.

Squadron Leader England's paper will, I feel sure, be of very great value to aircraft firms and others who are interested in performance tests as giving a resumé of the routine tests carried out at Martlesham.

Captain BROAD: There are two questions I should like to ask the lecturer.

First, regarding the method of ascertaining stalling speed; I notice that this is taken while in level flight. It seems to me that one would get greater accuracy if it was taken when the machine was losing height, because many modern machines, apart from being under control, are nowhere near stalling speed in level flight. Stalling speed is surely the speed which the airflow breaks down irrespective of the path of flight.

Secondly, what difference of speed do you get between your landing speed and stalling speed? With reference to flow meters, I have lately been using a small gauge which seems to cover this point. It consists of a small tank holding a gallon or half a gallon and has a sight gauge on the back. It is filled from the auxiliary or main tank and has markings on it. When in the air you turn on the tank and time your watch from one black mark on the gauge to the other. That gives you your consumption right away. You then fill it again to find your next consumption, and you can do it as many times as you like without landing or measuring. Each test takes only three or four minutes.

Flight Lieut. GRAY: I should like to say that with regard to the accuracy of test pilots, I do not think any pilot, however good he may be, can hope to get really accurate results unless he has two or three months' training at establishments like Farnborough or Martlesham; and I do not think it requires an exceptionally skilful pilot to become a first class test pilot, but he must have had more than the average experience on different types of aircraft and should be able to take a number of readings in the air and at the same time maintain the aircraft in the desired condition of flight. This part of a test pilot's work can only be perfected by much practice.

Mr. RAYNHAM: There is one point I would like to touch upon, and that is the testing of the manœuvring ability of new machines. I remember from the

days at Martlesham that there were many discussions on this subject, and I think that no decision was ever reached.

Probably Squadron Leader England can tell us what the present methods are. It seems to me that controllability tests are just as important on fighting machines as performance tests.

I congratulate Squadron Leader England very much on his lecture.

Capt. BULMAN: Squadron Leader England refers to the high degree of accuracy attained in performance testing at Martlesham Heath. Without wishing to belittle the efforts of the pilots, but merely to encourage others who are striving to obtain similar results, I must give my opinion that part of the credit is due to the "able technician." Engines do not perform uniformly on different days, particularly at height where the well known trouble of altitude control adjustment coupled with low air temperature occurs.

I, personally, have found considerable difficulty in obtaining comparative results on different days, particularly with regard to level speeds, which in my experience have varied as much as eight miles an hour during a half-hour's level run. The only explanation I can offer is the presence of considerable vertical air currents, and it seems to me important that a large number of readings should be taken and averaged by the technician.

With regard to flow meters, I think they are excellent and work very well under steady conditions. To my mind the chief difficulty appears to be the pulsations in the petrol supply, either the pump pumping air and petrol alternately or bumpy air conditions varying the effective gravity head. To add to these there is the possibility that the float chamber mechanism permits fuel to pass in gulps and does not put a steady demand on the fuel supply.

Flight Lieut. COMPER: I should like to comment on the question of the difficulties which are experienced in getting the necessary test observations in single-seater aircraft—especially those of a high speed nature.

Squadron Leader England has shown a slide of a test pilot "dressed up" for flight to great altitudes. In addition to wearing such elaborate clothing and equipment the same pilot has to maintain a perfect course and also make written notes of observations obtained from various instruments disposed all over the cockpit.

I am sure all will appreciate the extreme difficulties that a test pilot would encounter on a Schneider Cup seaplane—to take an extreme example.

An observer of some sort must be carried, and where accommodation does not permit the human variety, suitable apparatus must be provided to do the same work. This is just a development of existing methods and it seems that photography will provide a simple starting point.

Capt. UWINS: I am afraid Flight Lieutenant Comper has anticipated my remarks.

In Squadron Leader England's paper he rather showed the weakness of the present method of testing modern single-seater fighting scouts, because he said that on other machines the tests are taken at intervals of 1,000 feet, whereas on single-seater scouts they are taken when the pilot is able to do so.

As one who has had something to do with the development of the supercharged engine, I think we can have no indication of all the difficulties of taking accurate readings on supercharged scouts, because to run a supercharged engine efficiently is difficult enough in itself. I think, therefore, that we must look for a new instrument that will take observations automatically, either by a timing apparatus or by a clockwork measurement taking camera.

Squadron Leader R. DE H. HAIG: With regard to flow meters, Captain Broad talked about one that he has been using. We tried that at Martlesham

four years ago, and found that, due to the test pilots using their controls differently, we could not get consistent results.

There will never be any improvement until we get an automatic altitude control inter-connected with the altimeter as well.

I should like to endorse what was said at the end of the paper about the Martlesham reports. We certainly need much more thorough examination of machines when they have been through their performance trials, to eliminate any faults that may occur. I have been at Martlesham and Farnborough and seen machines that have been in service a long time, come through at Farnborough damaged through something that should have been noticed at Martlesham. It is not the fault of the people there, but I would suggest that if they would have an exchange of personnel between Martlesham and Farnborough it would help greatly, as Farnborough probably have more experience of flying than anyone else in the country.

Their personnel have been there a long time and have dealt with very many types of aircraft, probably more than at any other establishment in the country.

Capt. SAYERS: My experience of testing goes back to the early days when we first tried to establish a testing station at Grain. We did not get accuracies within 1 per cent. in those days, and some of our results would look very strange indeed to those at Martlesham to-day.

I notice that there still exists one of the troubles of the early days, that is, that Martlesham can never get the same results in weight as the manufacturers do. Nor could we, but we also found we could never get the same weight results twice on the same machine ourselves. Can Martlesham do this to-day?

Mr. LOWE-WYLDE: The lecturer mentioned the necessity of issuing information on structural methods to prevent recurring failures due to unsatisfactory structure practice and gave as an example the frequent failure of tail skids.

Though rather irrelative to the subject of his lecture, I should be glad if the lecturer can give us any further information, as a result of his wide experience of the testing of experimental machines, with regard to tail skid requirements.

I have been abroad, on the design of machines for a foreign Government, and met with tail skid troubles.

In Greece, where I have been, aerodromes are not at all like ours—there is no grass and the entire surface is a mass of small stones, resulting in general tail skid trouble to most types of machines.

I have also heard that many machines submitted to Martlesham for test have developed tail skid trouble, and as I suppose that certain methods must have shown up as being consistently unsatisfactory, I should be grateful if the lecturer would tell us of any points he has noticed in relation to tail skid design requirements.

Mr. MANNING: In Squadron Leader England's reference to the Farnborough tests there was one which he did not refer to; I mean the rolling test which was carried out on a specially prepared track on the aerodrome. It was certainly of use in improving the design of chassis. I have been at Farnborough in the early days and seen no less than four machines in different parts of that track under test, and it seems to me that in certain cases of, say, tail skids, such a test would still be very useful.

I believe that at one time a method of getting speeds was tried by flying the machine under test alongside another machine which had a carefully calibrated A.S.I. aboard. That might seem to have certain advantages and I shall be glad to hear whether this test is still being used.

I should like to hear the lecturer's remarks as to what steps are taken at

Martlesham when it is discovered, say, that a machine possesses some control vice in some way, or has any other similar defect.

Major KENNEDY: There is a point that has only been referred to by one other speaker and which has occupied my mind since the conclusion of the lecture, that is, the very definite statement by Squadron Leader England that in spite of the magnificent staff and the wonderful arrangements at Martlesham Heath and Farnborough for testing and reporting, it seems that we do not learn our lessons. Squadron Leader England stated that tail skids, which are definitely known to be unsatisfactory, go on being made and sent out by the manufacturers for service. That is a very definite and serious statement and I should therefore like to concentrate attention upon it. I congratulate him on his courage in voicing it. I do not know whether the responsibility lies with Martlesham Heath, or Farnborough, or with Kingsway, but I do feel that if we can do anything in the matter we ought to do it.

Mr. A. C. CLINTON: With regard to the rhythmic motion of machines in flight, to which the lecturer referred, I remember that we used to have a small instrument for recording longitudinal stability, but it could not be worked when one was flying in clouds or on a dull day. I wonder whether any instrument has been invented which would enable more accurate observations to be taken.

Mr. F. A. THOMAS: It is nine years since I was engaged in the practical testing of aeroplanes and I should like to ask the lecturer whether he realises that most of the tests described were carried out on Mr. Handley Page's aerodrome in 1917 and 1918. There does not seem to be much advance since that time. The only amplified test seems to be that of timing the speed of the aeroplane when flying close to the ground. The "ground speed" tests in 1918 were timed by the air speed indicator as it was considered "air speed" was much more important than speed relative to the ground. I can understand the difficulty of placing the pitot tube where it is not affected by eddying of the air due to position of struts, etc., and also the difficulty of obtaining a correct reading of "air speed" from any instrument fixed to the aeroplane. I suppose the timing method described is the only manner of obviating these difficulties.

Has the relative rumidity of the atmosphere any appreciable effect on performance, especially with large machines?

Mr. HANDLEY PAGE: A good many people have spoken from different points of view on this very admirable paper. I have had the pleasure of being with Squadron Leader England while he has been writing the paper, and I understood it was going to be a very bad paper; I have therefore been surprised in listening to it to find how good it is.

There are one or two points upon which I would like to touch.

Within the last few days there has been issued, by the National Advisory Committee for Aeronautics in America, a note, in which they deal with the question of a heavily-loaded machine taking-off and rapidly reaching its ceiling. They raise the question that a machine near the ground lifts very much more than when it gets a few feet off the ground—say, 50 or 60 feet. Also they find a marked difference between the performance of a machine flying more than half its span above the ground, and when at a lesser altitude than that. I wonder whether in the testing at Martlesham Heath, Squadron Leader England has come across any differences in the actual speed of a machine when close to the ground and at a height greater than its semi-span. It would seem from the American note that one should be able to find some difference in the performance.

What are the differences in performance that have been measured due to different weather conditions?

Captain Bulman has referred to the fact that we may very often get quite a wide margin of discrepancies in machines, and I, personally, have always

thought that there must be something wrong with the atmosphere at Martlesham Heath, because the results invariably seem to vary from the figures one would like. I never realised before that it may be due to some scientific difference of which the industry was not aware.

The CHAIRMAN: I should like to ask what is the particular type of flow meter that has been developed and which seems to promise considerable success in the near future.

Regarding the question of the satisfactory design of tail skids and the like, I should like to remind you that in the old days there was machinery for advising contracting firms on points of that nature. There was a regular circularisation of suitable notes from the Technical Department of the Royal Naval Air Service over ten years ago, to deal with cases of this kind.

I notice that the lecturer, when referring to ancient methods of testing, did not tell us of the slow speed tests carried out two or three feet above the ground. In those days most machines were fitted with rotary engines and any attempts to get slow speed tests were both exciting and uncertain.

REPLY TO DISCUSSION

The discussion has centred round

Flow meters.
Unexpected phenomena whilst flying.
Training of test pilots, and
Difficulties in taking readings in high performance aircraft.

Dealing with the first, the flow meter, apart from having seen and tested several different types, I am forced to admit that my knowledge on this subject is extremely limited. Nevertheless, it is gratifying to hear Flight Lieutenant Capon state that they have at last reached a stage whereby we are promised a satisfactory meter, working under all conditions.

Captain Broad's system of measuring petrol consumption is decidedly better than the Martlesham method, which I described in my paper; whilst agreeing with Squadron Leader Haig that it has its weak points, I consider it in advance of anything actually being used at the present time. Captain Broad and his firm deserve congratulation on tackling this important subject in the way they have.

Colonel Tizard and others in the discussion have referred to curious unexpected phenomena which may be encountered during flight. Major Bulman and also Mr. Handley Page have given definite examples of what I consider would come under this heading. There is no doubt that our knowledge of air currents and temperature inversions, and the effect they have on aircraft, is extremely limited.

The most interesting experience in my flying career occurred whilst near Gibraltar in 1915. I was flying towards the Rock from the south-west—a westerly wind was blowing at the time—at a height of about 2,000 ft. At a distance of about three miles from the Rock, without in any way altering the air speed or engine revolutions, the aircraft commenced to gain height. When I was within half a mile of the Rock, it started without any action on my part to descend so rapidly that I was forced to increase the engine revolutions and turn away from the Rock. The cause of this was undoubtedly due to up and down "trends," nevertheless I quote it as an interesting phenomena.

The report, issued by the National Advisory Committee for Aeronautics in America, which Mr. Handley Page quoted, relating to the difference between the performance of a machine flying more than half its span above the ground

is interesting; similar experiences have been obtained elsewhere. Certain aircraft of big dimensions have been found to possess an initial rate of climb for the first 100 ft. greater than that which is accounted for, and for which I have no satisfactory explanation.

It is interesting to hear such well-known and able test pilots, who have contributed to this discussion, stating that the limits of the pilot in high performance aircraft have nearly been reached; that is in so far as the pilot is expected to record figures and observations made during a climb. I fully agree with Captain Uwins' remarks, and unless some form of instrument is developed on the style of the cash register, whereby one presses a key which records height, time, temperature, etc., I do not see how any pilot is going to manipulate a super-charged engine and at the same time record all the figures.

To revert to the training of test pilots, the popular opinion is that a successful test pilot must be something abnormal in the way of pilots. This opinion is erroneous. It goes without saying that a successful test pilot must have flown numerous different types of aircraft and had a varied experience. Patience and perseverance play the most important part in the success of a test pilot. I well remember my first climb made at Martlesham. The day was very cold, and needless to say I was adequately wrapped up. Before I had got to 5,000 ft. I was in a terrific state of bodily heat, as trying to write down figures in a rapidly climbing Scout for the first time is not as easy as one would at first imagine. Even at 18,000 ft. I would have been glad to have been able to abandon quite a lot of my extra clothing.

I view with concern the policy of sending inexperienced pilots to Testing Establishments for training as test pilots. It is unfair to the individuals themselves, and likewise to those who build the aircraft, because however competent and keen they may be, they cannot possess the experience which is necessary for their work. Without wishing to say too much about the pilots' side, those who have been to Martlesham, Farnborough and Felixstowe, will agree that although a pilot may have flown some 3000-4000 hours, he is of little value as a test pilot until he has been in training for at least six months.

Captain Broad raised the question of the method of ascertaining stalling speed. Actual stalling speed, I consider, is the lowest speed at which a pilot can control his aircraft with losing height. Whilst admitting that this also is not a satisfactory definition, I do not agree with Captain Broad that the stalling speed of a machine should be taken as from the moment when the machine commences to lose height; nowadays, with the perfection of control and anti-stalling devices, this may lead to difficulty.

The question of difference between stalling and landing speed varies with the type of undercarriage and the proximity of the lower plane to the ground. Some aircraft possess a landing speed of seven to eight miles an hour below their stalling speed.

I am glad Colonel Tizard has mentioned the name of Major Mills. In a paper such as mine, it is impracticable always to give credit where credit is due. Nevertheless, as Colonel Tizard and Major Mills were the first in this particular field of activity I feel that they deserve due credit for their initiative and hard work. I only hope that those entrusted at the Testing Establishments will continue building on the foundation which Colonel Tizard and Major Mills laid so well. As Colonel Tizard has pointed out, military organisation and discipline are all-important, but if the technical work of the establishments is to continue on an efficient basis, such organisation and discipline must be subservient to the main work.

I am glad Mr. Manning pointed out that I had omitted to mention two very important tests. The old method of carefully calibrating the A.S.I. and then

flying two aircraft side by side is carried out at the present day and is in every way satisfactory.

Major Kennedy very properly asked a question concerning tail skids, which I cannot very well answer. Nevertheless, the weaknesses are known and occur, and until definite action is taken will go on re-occurring.

With regard to the instrument to which Mr. Clinton refers, for the rhythmic motion of the machines, no other than the recording A.S.I. is used for longitudinal stability.

I do not agree with Mr. Thomas' remarks wherein he stated that there has been little advance in the tests carried out nowadays, compared with those of 1917-18.

SEAPLANES

Fifteen Years of Naval Aviation

BY GENERAL A. GUIDONI.

In 1908 the flights of the Wright Brothers and of Mr. de la Grange turned my attention to aviation. A graduate from engineering and naval constructors' schools and a Lieutenant in the R.N.C.C., I first devoted myself to building an aerodynamical whirling arm (Photo 1) which enabled me to carry out some research on aerofoils and airscrew models. As in the Froude's tank, forces, spaces, times and revolutions were registered on continuous diagrams.

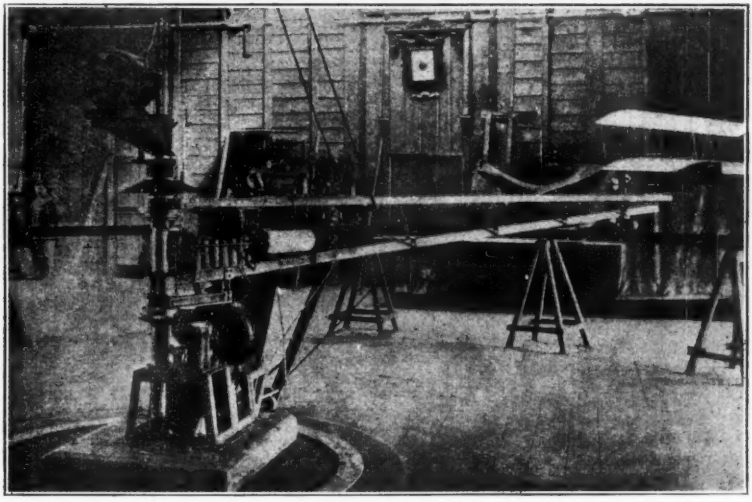


Photo 1.

Then, in 1910, I started the construction of my first aeroplane, which never went in the air, although it had been provided with an automatic stability device.

From the beginning I understood the importance of being a pilot myself, before taking any risks, so I obtained my licence in 1911, on a land Farman. At that time licences were granted in a very few hours. I remember I had been only twelve times in the air and had had two hours' flying training altogether.

Then I went back to my machine. I forgot all about stability, put on two floats and the 5th November, 1911, I succeeded in taking off (Photo 2) in what can be regarded as the first flight of an Italian seaplane. I had no experience in piloting seaplanes, but everything went well.

Nothing succeeds as success. So the first flight enabled me to obtain some credits from the Navy and I was able to build up a monoplane and another biplane with the same system of floats. These were original ones, as from the very beginning I used only a cylindrical type of float with hydrovanes.

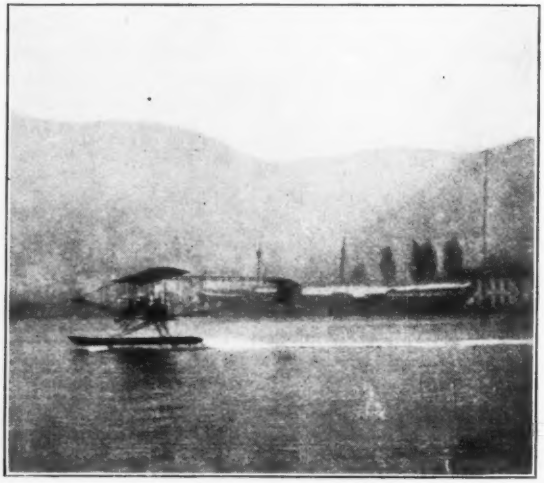


Photo 2.

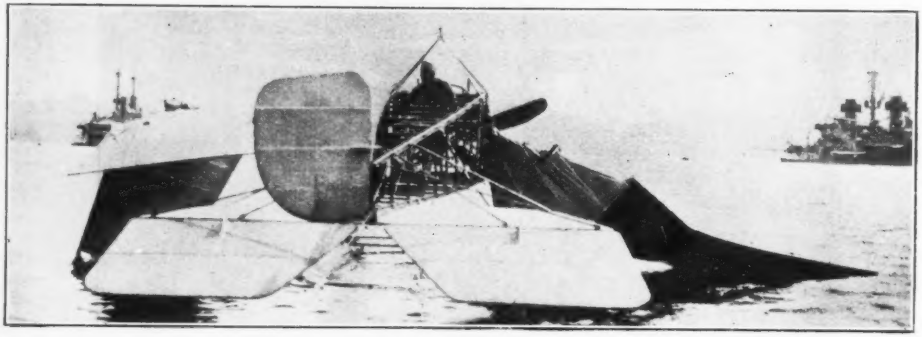


Photo 3.

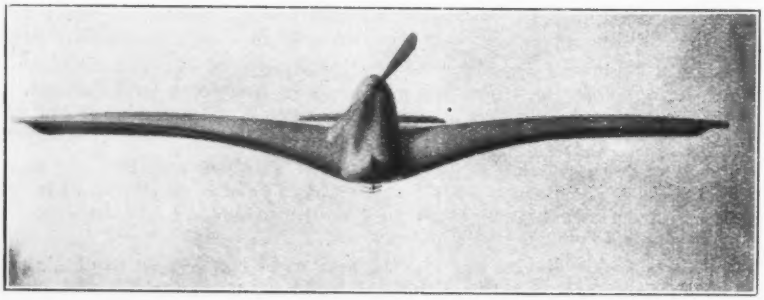


Photo 4.

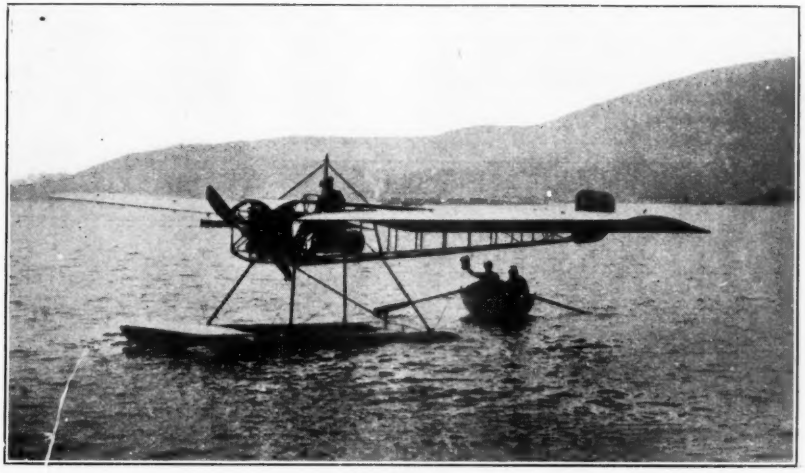
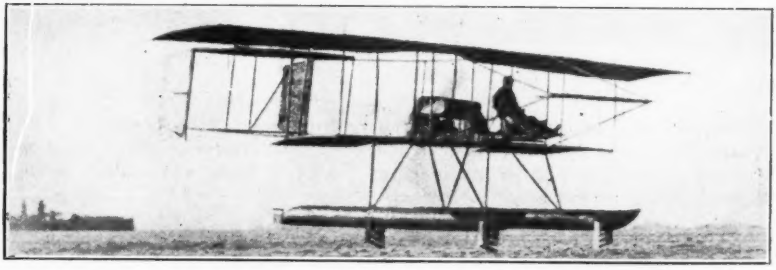


Photo 5.



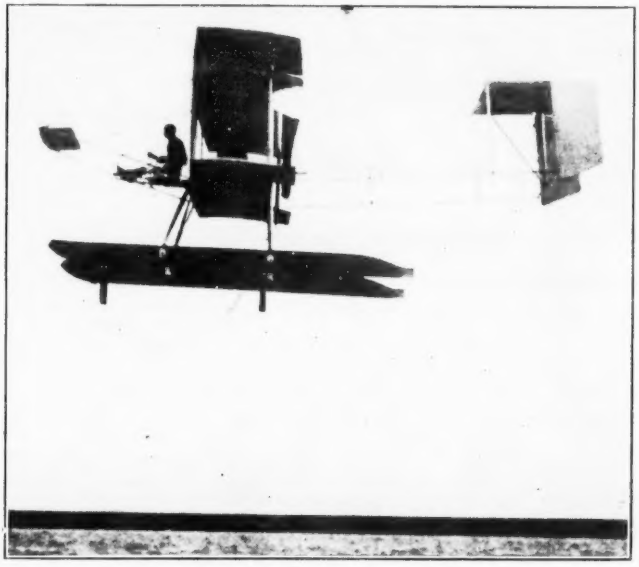


Photo 6.

In one of these experimental tests I had a very bad experience, owing to the breaking of both wings. I was able to land, or drop, without mishap, being then towed to shore (Photo 3).

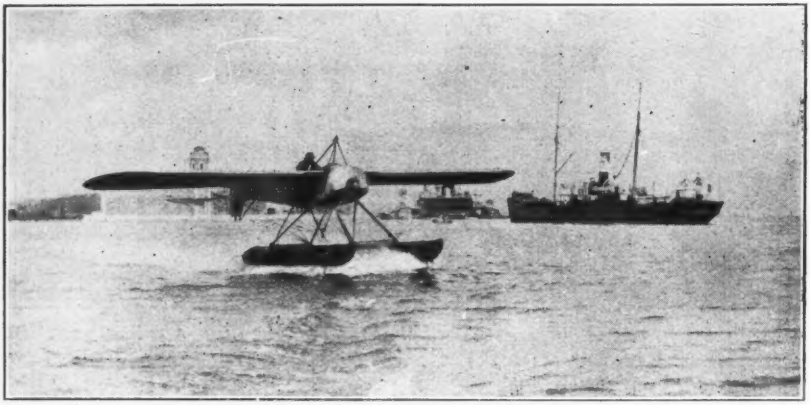


PHOTO 7.

All these tests were carried on in the Spezia Bay, where I was on duty in the Naval Yard. In 1912 the Navy started the first organisation of aviation in Venice and I went there with my machine, creating quite a sensation amongst the "gondolieri" of the peaceful lagoon.

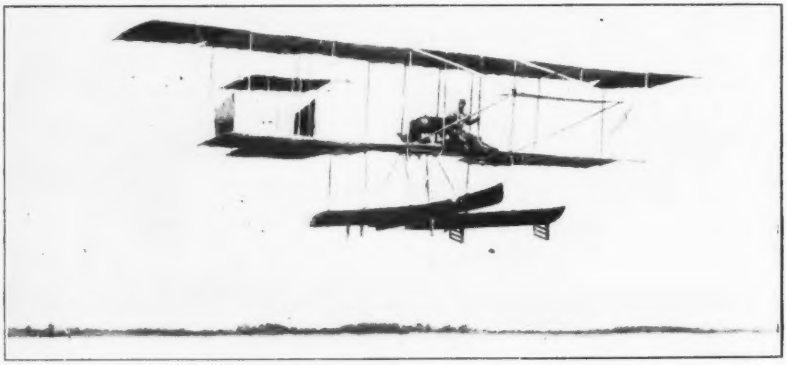


PHOTO 8.

I can remember the first cantilever floating wing (Photo 4) in which the monococque system was used. Again the hydrovanes can be seen under the float, as I was very fond of them. Col. Croco, Com. Ginocchio, Com. Calderara and myself had a particular propensity for this system, which permits a separation of the functions of static buoyancy from that of dynamical sustentation.

We were all working in the path of Signor Forlanini, to whom credit must be given for this invention. Signor Forlanini is also to be credited with the first Italian airship developed there.

As a pilot, I praised the smooth landing on the vanes, also on rough sea, so I forgot the other disadvantages (Photos 5, 6, 7).

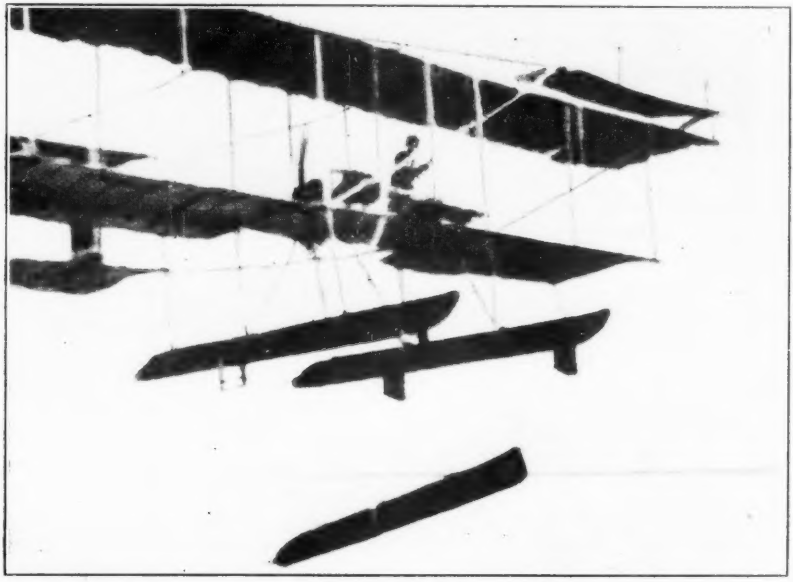


PHOTO 9.

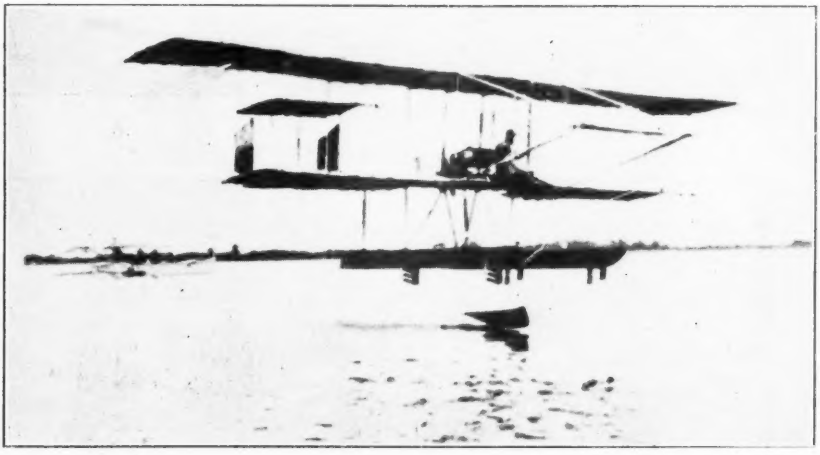


PHOTO 10.

After some work of different kind, and in particular on aluminium floats which were very successful, I was ordered in 1912 to help Mr. Pateras Pescara, who had suggested to the Navy the building of a torpedo-plane. Mr. Pateras

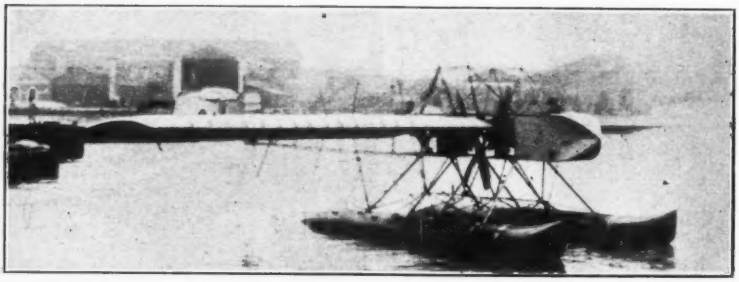


Photo 11.

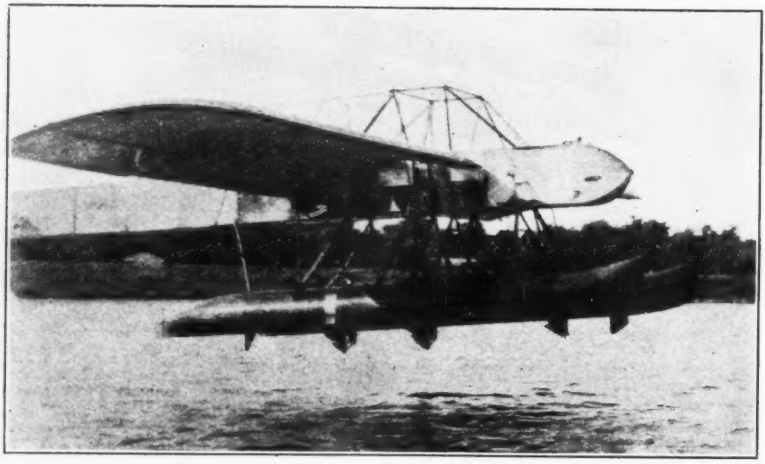


Photo 12.

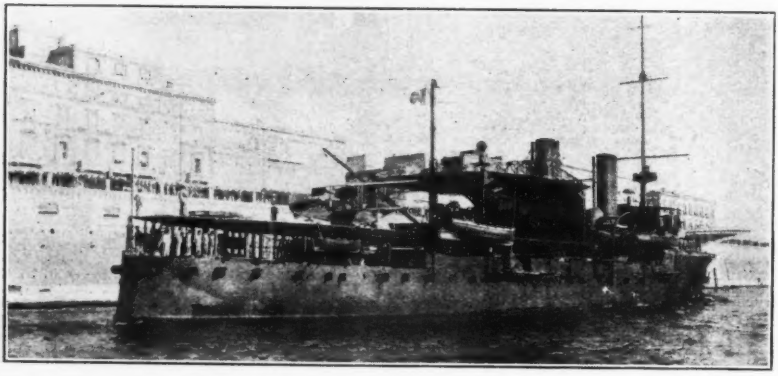


Photo 13.

Pescara was a lawyer. Had he been a technical man he would probably have been refused permission to try out his scheme.

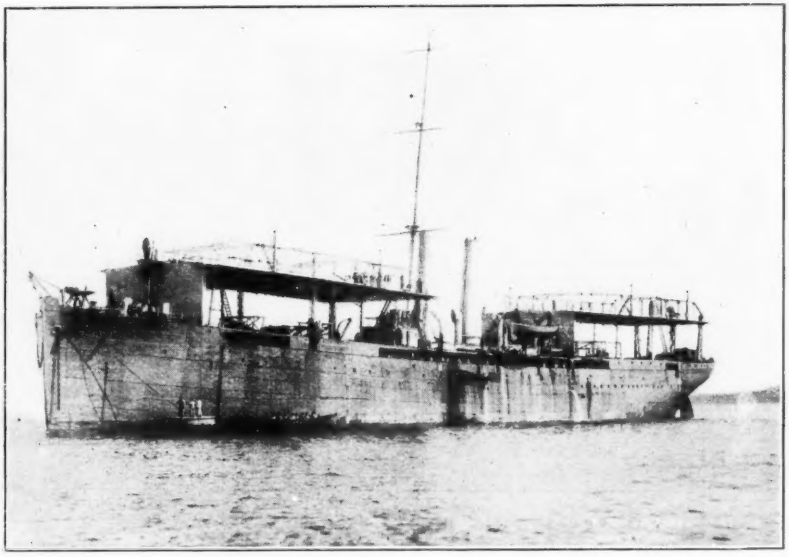


PHOTO 14.

At that time a maximum weight of 20 pounds only had been dropped from an aeroplane; that was much below the 700 pounds of a torpedo (Photos 8, 9, 10).

PHOTO 15.

But with my faithful Farman I succeeded in dropping 170 pounds, so I concluded that with a machine of 6000 pounds total weight it would be possible to drop a small torpedo. I went on with the building of the torpedo-plane. It was a large monoplane with two hydrovane floats and two Gnome 200 h.p. engines in tandem (Photo 11).

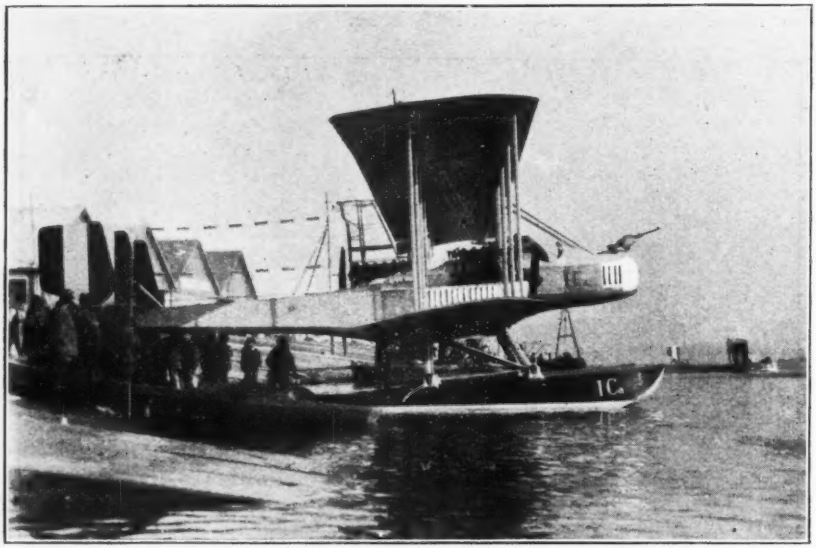


Photo 16.

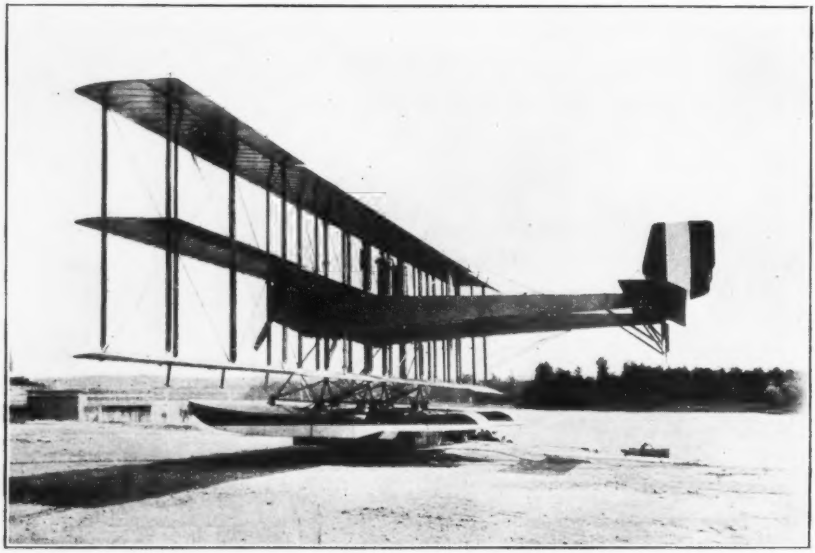


Photo 17.

The fuselage was in steel tube and the wings in wood and aluminium. With this machine I succeeded in February, 1914, in dropping a torpedo of 750 pounds; and perhaps this can be considered as the first torpedo launching (Photo 12). These torpedo launches were repeated many times and I never found any difficulty in flying at six to eight feet and dropping the torpedo.

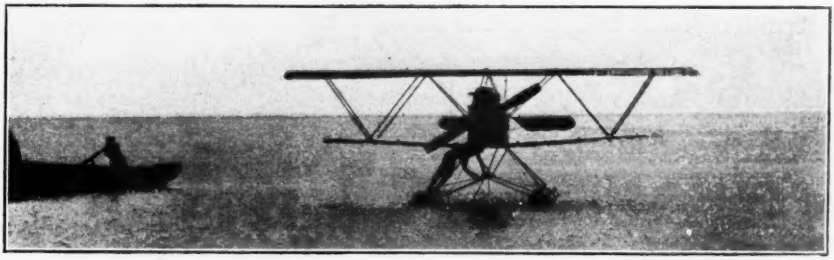


PHOTO 18.

Then the war came and I had to put aside my tests and devote myself to " Elba " (Photo 13) and " Europa," which was our first Italian seaplane carrier (Photo 14). I was on board of the " Elba " with a little scout of 100 Gnome h.p. on my design, which I liked very much (Photo 15).

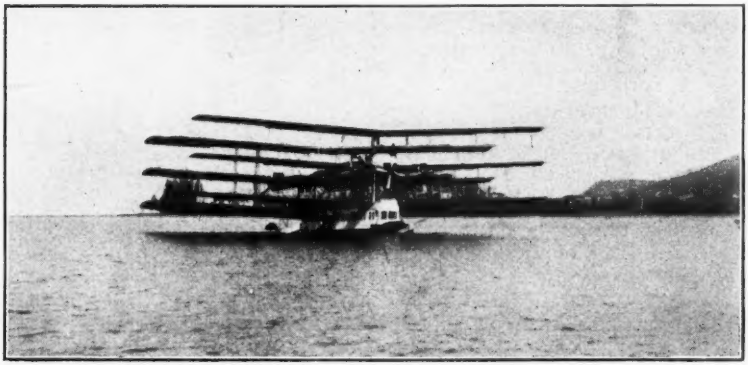


PHOTO 19.

During the war I worked on the conversion of big aeroplanes to seaplanes, by fitting them with two floats (Photos 16 and 17). A scout machine (S.V.A.) also was fitted with hydrovane floats (Photo 18).

Then after the war I joined Signor Caproni and developed a new idea in hydrovanes, specially adapted to very large machines (Photos 19 and 20).

This was my last work before being appointed Chief of Technical Services in the Regia Aeronautica.

The Early Seaplanes

From the very beginning of aviation, research was directed to enable the

aeroplane to take-off and alight in water. In 1911 no less that ten different makes of seaplanes were shown at Monaco.

England, the United States and France generally solved the problem by substituting for the landing gear boats, central or lateral, of different form, but all provided with a bottom plane surface. In Italy research on seaplanes had another direction.

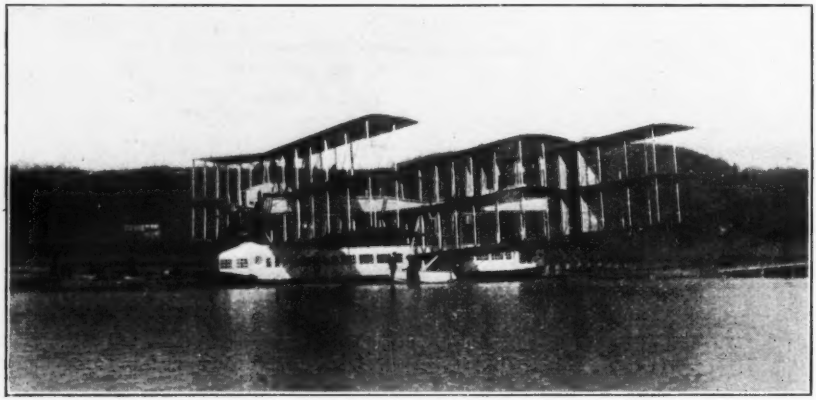


PHOTO 20.

The Work of Sig. Forlanini and Col. Crocco

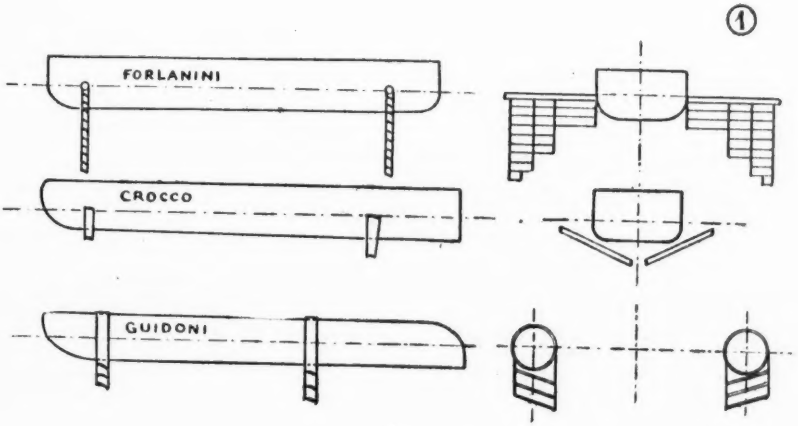
Signor Forlanini, a very clever and modest engineer, who in 1878 succeeded in operating a small self-propelled steam helicopter, had since 1898 devoted himself to experimental research on very fast small craft, which was supported, when at full speed, not by the hydrostatic lift of the craft, but by the hydrodynamical lift of some really small wings or vanes, fitted under the craft.

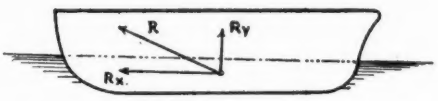
Signor Forlanini was at that time very busy in building a semi-rigid airship with Capt. Dal Fabbro, but he managed in 1905 to complete the tests of his hydrovaned boat. Some of these tests I was allowed to witness. Signor Forlanini had adopted a series of horizontal parallel vanes, decreasing from the top to the bottom (Fig. 1).

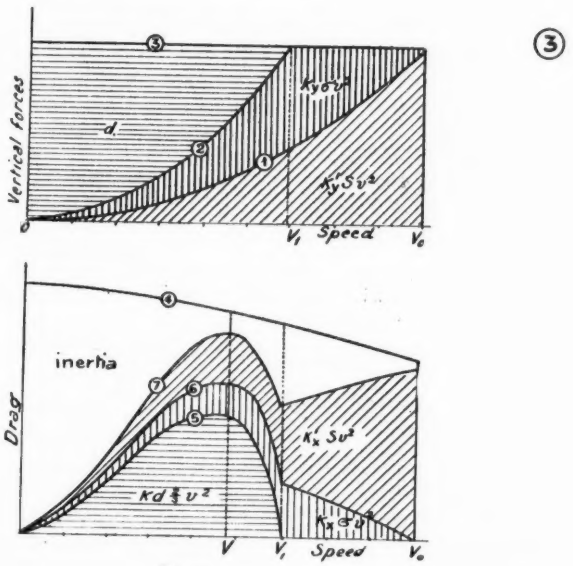
About this time Col. Crocco was considering the same problem on similar lines, but he employed a unique V-vane, decreasing from the extremities to the middle, both in width and angle of attack. The boat of Col. Crocco had later very good results, reaching a speed of about 50 m.p.h.

The fundamentals of the design both of Forlanini and Crocco types are easy to understand; in fact the hydrovane area required to support the boat decreases with the square of the speed; in the Forlanini the upper vanes emerge from the water as the speed increases; the last vane, which for a boat of three tons was a rectangle 4in. by 12in., working only at the maximum speed. In the Crocco type, the vane, being a monoplane with a lateral V of about 12°, the same result is achieved in a different way.

As the speed increases the vane emerges gradually from the water till only the central part is working. It is quite clear that both systems give a good lateral stability because any lateral inclination has the effect of submerging a greater vane area on that side, giving rise to a lateral force which straightens the craft.


①
FORLANINI
CROCCO
GUIDONI


②
R
Ry
Rx


③
Vertical forces
d
Ky σ² v²
Kz S v²
V1 Speed V0
④
inertia
Drag
Kx Su²
Kd ½ v²
V V1 Speed V0

FIGS. 1-3.

It must be pointed out that neither Forlanini's nor Crocco-Ricaldoni's devices were designed for aircraft, but only for boat purposes. The designers were confronted with the problem of lateral equilibrium and they solved it in a different way, yet on the same principle, *i.e.*, placing the hydro surfaces in such a position that the banking of the boat would cause an increase of the hydrodynamic reaction on the side and so re-establish the equilibrium.

Both the designers succeeded in this sense, that the equilibrium at very high speed was absolutely stable; but one must admit that the Crocco device was more simple and elegant.

These experiences took place in 1908; later in 1911 Col. Crocco started the test of a seaplane with a hydrovaned boat, but owing to a too reduced area he could not get the machine over the critical speed. He had the machine drawn by a very fast motor boat and succeeded in overcoming the critical speed and allowing the aircraft to take-off. It was wrecked at the first flight.

The Theory of Seaplane Floats

A floating craft at standstill is supported only by the static pressure of water; but if moving, part of its weight will be compensated by the hydrodynamical reaction of water and the remaining part by the static pressure.

Indeed, the movement of a craft in water gives rise to a number of reactions, which have a resultant force R (Fig. 2). The vertical component Ry of this force depends entirely on form and speed. Sometimes it is practically nil, sometimes it is very little, but at other times it is very important.

The drag can be supposed as formed by two parts, one due to hydrodynamical action and the other to static pressure. If

D = Displacement at standstill.
d = Displacement at speed v.
v = Speed.
W = Weight of the craft.
R_x = Drag.
R_y = Lift.
$W = D$.
$W = R_y = d + K_y v^2$.
$R_x = k d^{2/3} v^2 + K_x v^2$.

As already pointed out, this distinction between statical and dynamical support can be drawn for any form of craft and for any value of the displacement.

There will always be a speed at which the weight of the craft is entirely supported by the dynamical lift. This speed may be very small for small craft, but it is very high for heavy craft.

In this last case $K_y v^2$ and $K_x v^2$ being very small at ordinary speed, they can be neglected.

It should be possible, by tank tests, to find out the value of K_y and K_x for any form of craft; their calculation in some cases is impossible.

The problem is simplified considerably in the case of a seaplane fitted with hydrovane floats, that is, with floats of more or less cylindrical form, provided with additional hydrodynamical surfaces. If

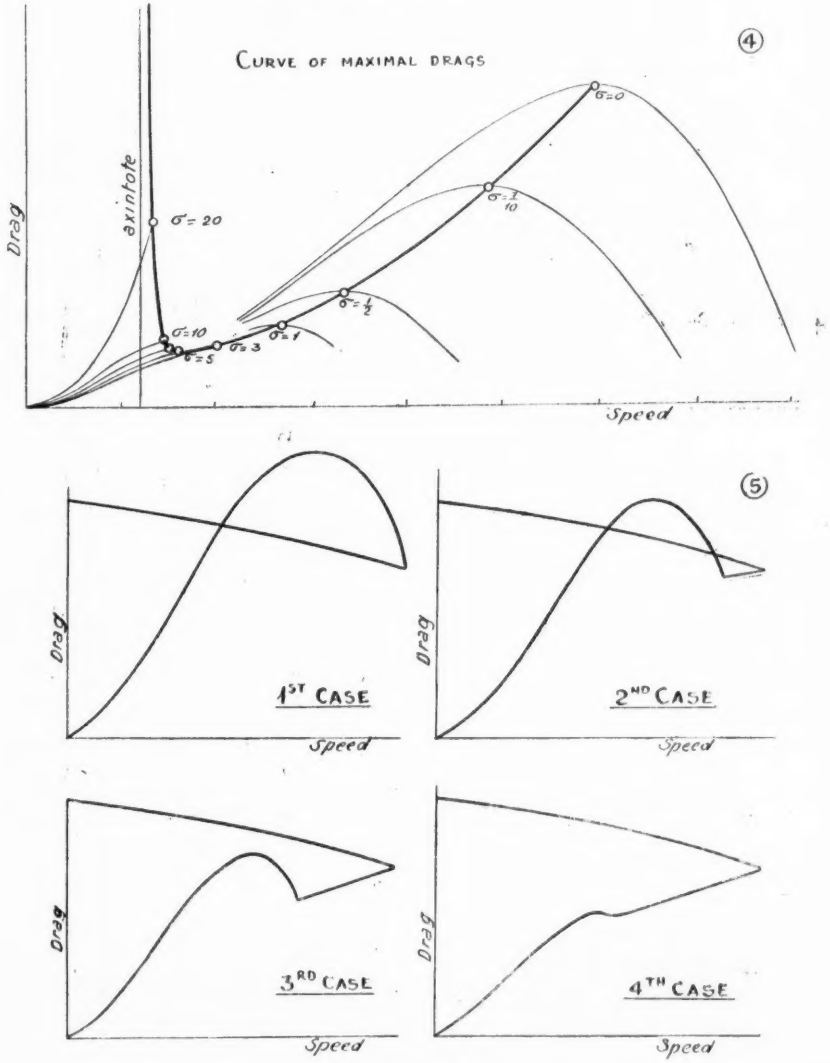
k'_y k'_x are coefficients of lift and drag in the air.
S = wing area.
k_y k_x are coefficients of lift and drag in the water.
σ = hydrovane area.

Then at any moment the weight W of the machine is supported by

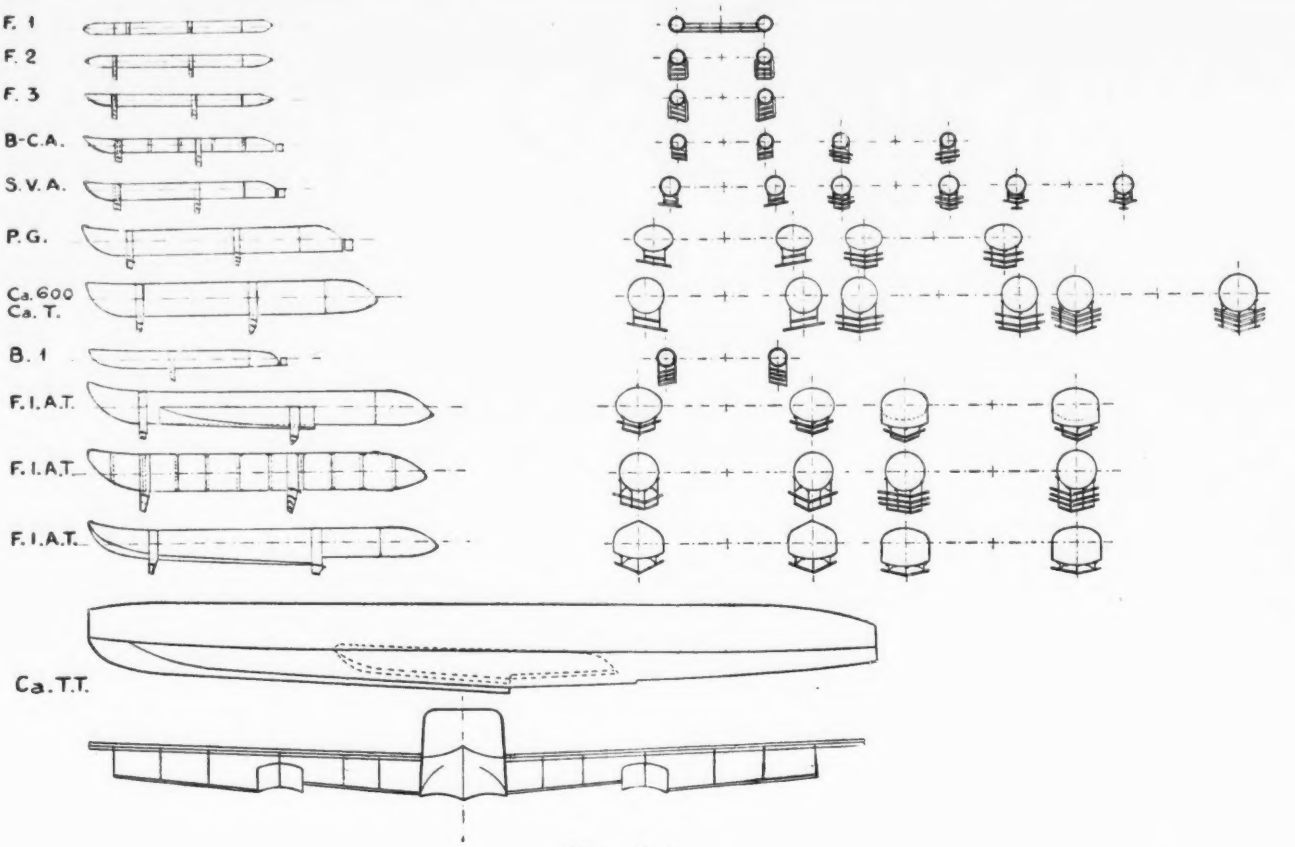
(a) The lift of the wings: $k'_y S \cdot v^2$.
(b) The lift of the hydrovanes: $k_y \sigma \cdot v^2$.
(c) The hydrostatic support of floats: d.

The total drag R consists of

(a) The air resistance: $k'_x S \cdot v^2$.
(b) The drag of hydrovanes: $k_x \sigma \cdot v^2$.
(c) The drag of floats: $k d^{2/3} v^2$.



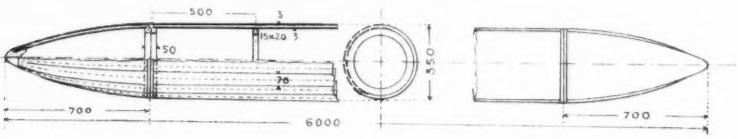
FIGS. 4 AND 5.



FIGS. 6 AND 7.

Owing to the cylindrical form of the floats, it can be assumed that they have no hydrodynamical lift, so the three parts (*a*), (*b*) and (*c*) of lift and drag can be very easily calculated by the expression given above.

$$W = d + k'_y S v^2 + k_y \sigma v^2$$
$$R_x = k d^{2/3} v^2 + k'_x S v^2 + k_x \sigma v^2$$



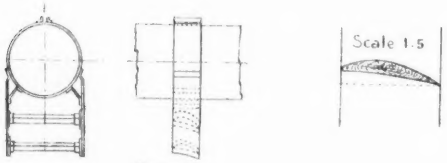
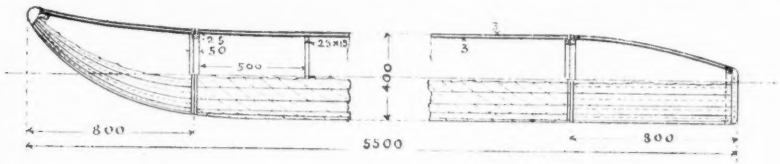


FIG. 8.

The tracing of curves of vertical and horizontal forces gives a graphic representation of the variation of dynamical and statical lift and drag (Fig. 3).



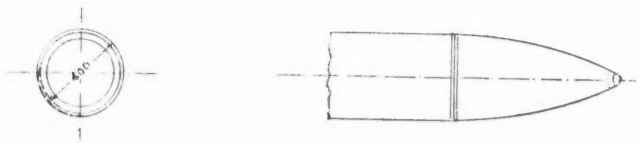


FIG. 9.

The two equations above can give an analytical solution of the problem. Solving the first for d and substituting in the second, we have an expression

$$R_x = (A - Bv^2)\, v^2 \sigma + (C + DW - Ev^2)\, v^2$$

equating the derivate to zero

$$(A - 2BV^2)\, \sigma + C + 2DW - 2EV^2 = 0$$
$$V = (A\sigma + C + DW)^{\frac{1}{2}} / (2B\sigma + 2E)^{\frac{1}{2}}$$

V is the critical speed to which corresponds a maximum value of the drag R_{max}.

Then the drag decreases to a minimum value, which corresponds to the gliding speed V_1. At this speed the static support of floats is nil, for they are clear of the water. The craft is entirely supported by hydrovanes and wings and its speed increases till the flying state V_0 is reached. Between V_1 and V_0 the drag is practically constant or slightly increasing.

$$W = k'_y S V^2_1 + k_y \sigma V^2_1$$
$$V_1 = W^{\frac{1}{2}} / (k'_y S + k_y \sigma)^{\frac{1}{2}}$$
$$R_g = k'_x S v^2_1 + k_x \sigma V^2_1$$

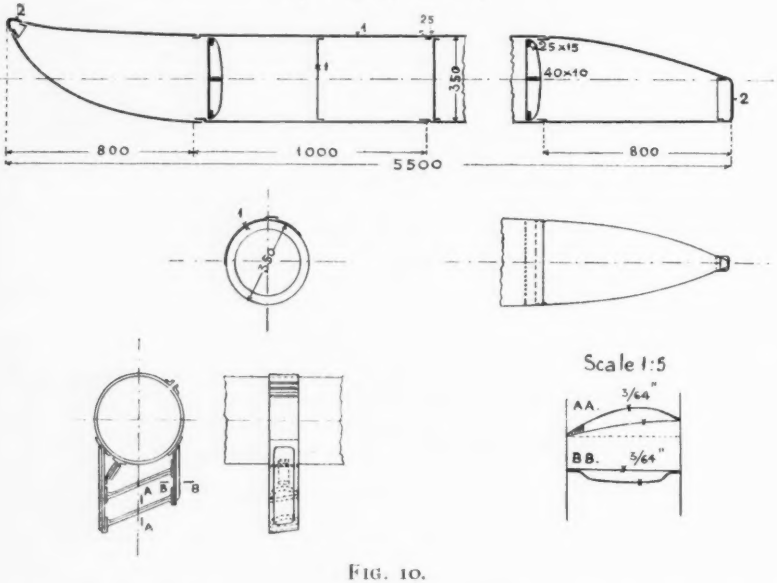


FIG. 10.

Tracing the curve $R_{max} - V$ for a given weight W, it can be found that the R_{max} decreases when the area of hydrovanes increases till it reaches a minimum value.

At this particular point the critical speed and gliding speed have the same value, as have the critical drag and the gliding drag.

It can be assumed that this is the optimum value of the area of hydrovanes (Fig. 4). Any further increase of the area would mean only an increase of drag.

The curves in some particular cases give a very neat idea of proportion and form of the total drag curve, the maximum point in correspondence of the critical speed V, the gliding drag and speed V_1 and the flying speed V_0.

The influence which the area of hydrovanes has on the total drag is also very evident and its importance more appreciable if the thrust curve is also indicated.

We report on the curves four cases:—

1st Case: Area nil.

2nd Case: Area not sufficient to reduce the drag under the value of propeller thrust.

3rd Case: Area large enough to ensure a good taking-off.

4th Case: Area a maximum. (Fig. 5.)

My Own Researches

Having witnessed some of the trials of the Forlanini boat, I was impressed with the ingeniousness and the possibilities of this system. So when in 1910 I designed my first seaplane, I put on it the Forlanini type of floats, but soon realised that they were no good for a seaplane. The change from one vane to the other gave severe bumps to the machine and produced changes impossible to control.

The Crocco system gave a too small area owing to the size of the floats and, astonishing though it may appear, I did not know at that time of his work.

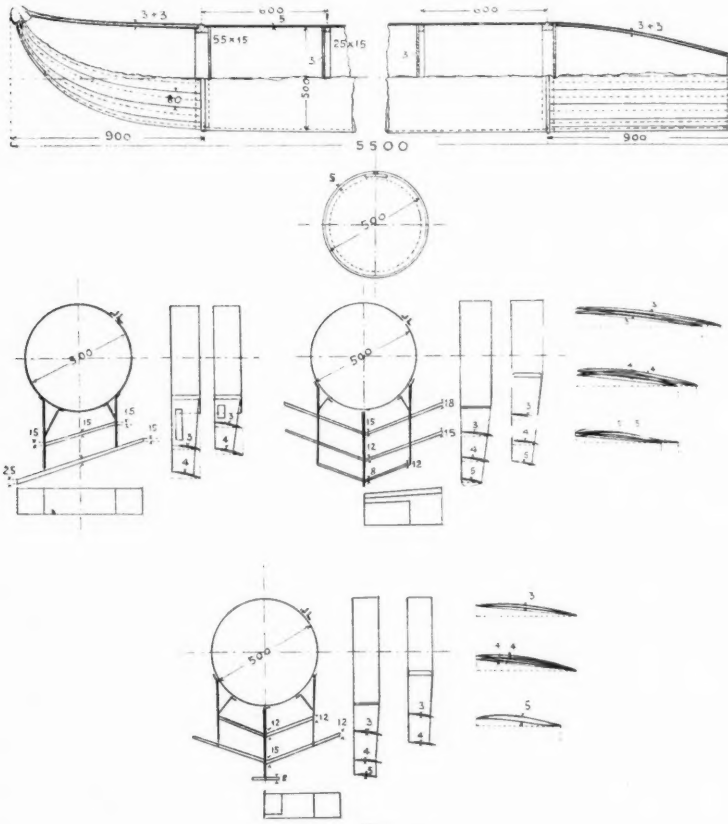


FIG. 11.

In my first test, using a two floats seaplane, I placed the hydroplanes between the floats; this proved unsatisfactory, because the floats would never get out of water, the drag at the getting-off speed being too high (Fig. 7, F1). Then I tried the Forlanini vanes under the floats, but without success (Fig. 7, F2).

My idea was then to have the hydro area divided in a multiplane with two or three legs; the vanes would be parallel and with a side inclination, the low end of each one being lower than the high end of the following vane (Fig. 7, F3).

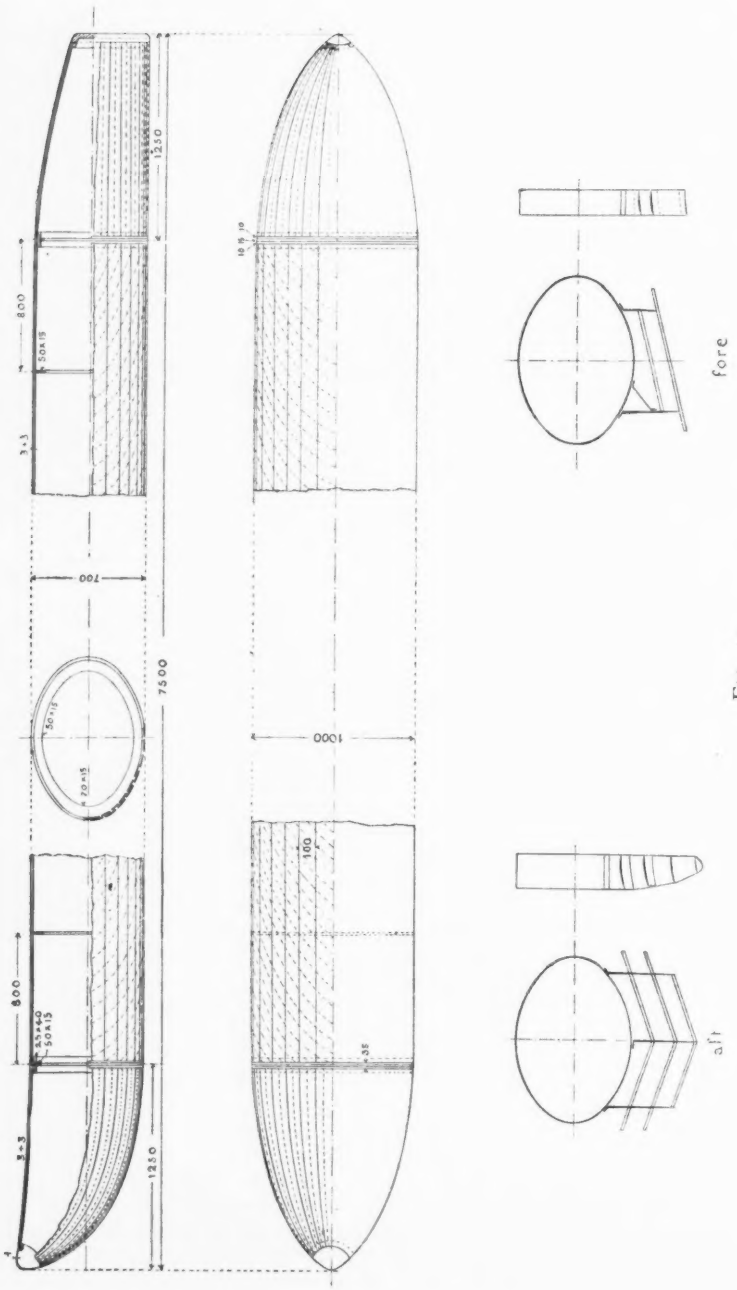

1230
800
50x15
3x3
700
7500
1000
100
35
800
50x15
3x3
1230
fore
aft

FIG. 12.

This design had the advantage of the Crocco vane, because it gave a gradual variation of hydro area when emerging from water, and it had at the same time the advantage of the Forlanini's, in giving a sufficient hydro area with a considerable depth and a reduced width.

I had then to improve the device and find out many things about the correct area, position of vanes, angle of attack, aerofoil, etc., before I could get a satisfactory result.

" Provando e riprovando " was my motto, but at the same time I tried to evolve the theory of the jumping due to the vanes.

The first set of vanes (Fig. 7, F1) was built of steel plate and were very heavy. I tried wood with success (F2) and aluminium, which proved the best (C.A.).

In order to be able to move the vanes along the float, they were mounted on rings of steel plate or aluminium. The planes I used in this first stage of research were an old Farman 1909, F.1, and similar improved machines F.2 and F.3, built at the Navy Yard. Two monoplanes (N.B.) were also tested (Figs. 7, 9, 16). The first floats had two wooden plankings, outside and inside, which gave a very strong and durable construction. In the second type the inner plankings were elicoidal and the outer longitudinal, with an oiled fabric between them; the two sheets were united by copper rivets.

The body was cylindrical with two heads; water rudders proved necessary in mono-engined machines.

Although the wood floats were always watertight, I found a great improvement both in building and operating them by the substitution of the wood with aluminium.

At that time (1912) duralumin was not available, so I used sheets of aluminium 1/25 in. thick.

The diameter being only 13 in., with one sheet of 40 in. by 80 in., I could build a ring of 80 in. length.

The riveting in aluminium was very easy, provided that some hand holes were opened in the deck.

The float was strengthened by watertight bulkheads (Figs. 10—17). Aluminium floats proved very successful. One pair lasted me two years and a half, being in salt water every two days, without the slightest sign of corrosion. At that time engines were not so reliable and to remain on the sea for some hours, waiting for relief, was not an unusual experience, so one had to rely on one's floats for safety.

Increasing the power and speed of machines, I found the wood vanes inadequate. I tried aluminium sheet vanes and then I standardised a set of steel vanes, which proved to be the right sort for any kind of machine, provided the size, thickness and shape were designed according to the power, speed and weight of the machine.

I used the ordinary steel plates, reducing them at the grinding wheel and welding the legs to the surfaces. In the construction of the torpedo plane P.G. I was faced with very very great difficulties; the design was made in 1913 (Figs. 12—18).

Wood floats and steel hydrovanes were made very easily, because I had already a good experience, but I had trouble in providing:—

(*a*) A monoplane semi-thick wing of 60 ft. span in aluminium and wood.
(*b*) Two tandem propellers, according to the Green theory, in order to get a maximum efficiency.
(*c*) A fuselage and tail planes in welded steel tubes.

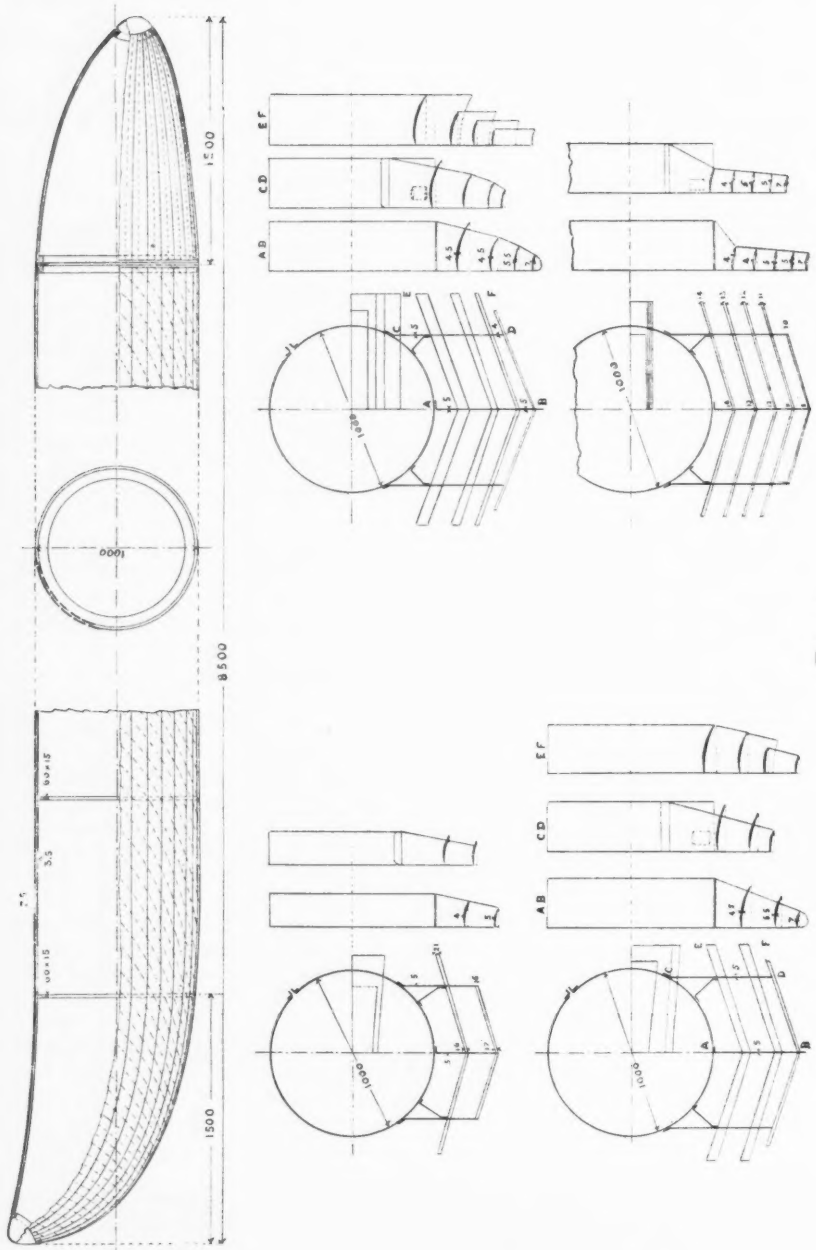


FIG. 13.

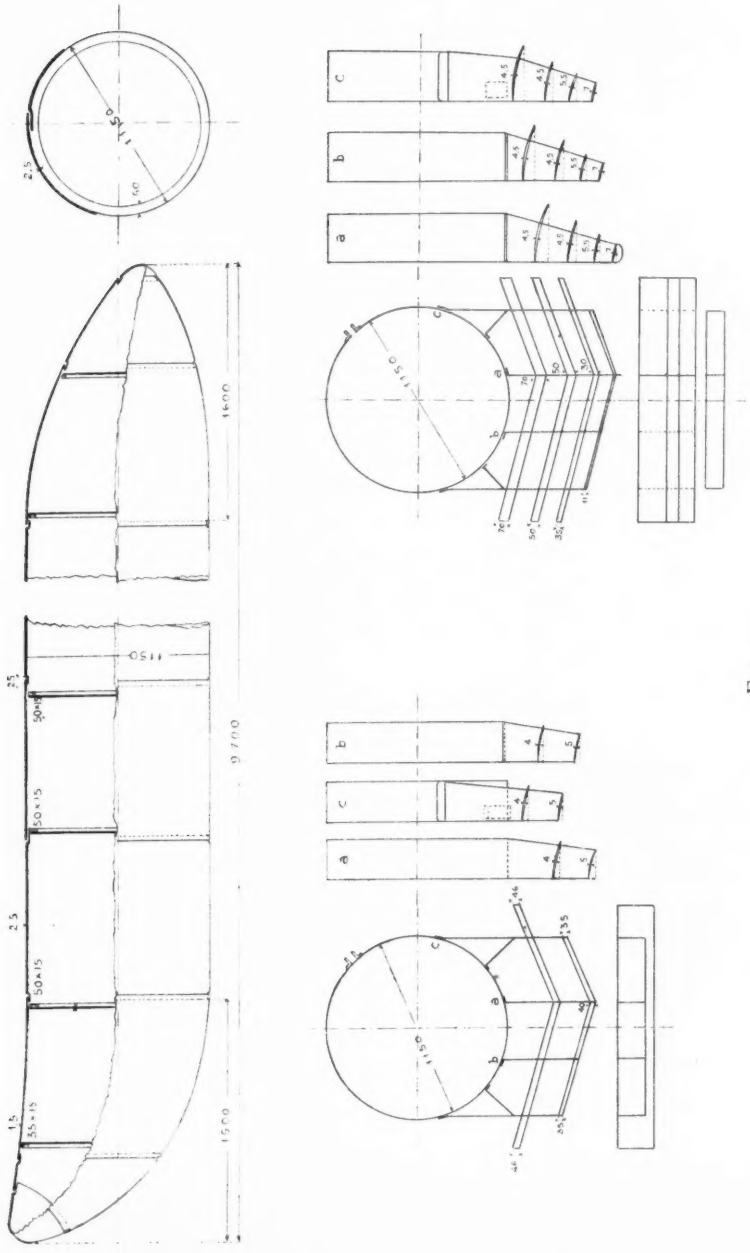


FIG. 14.

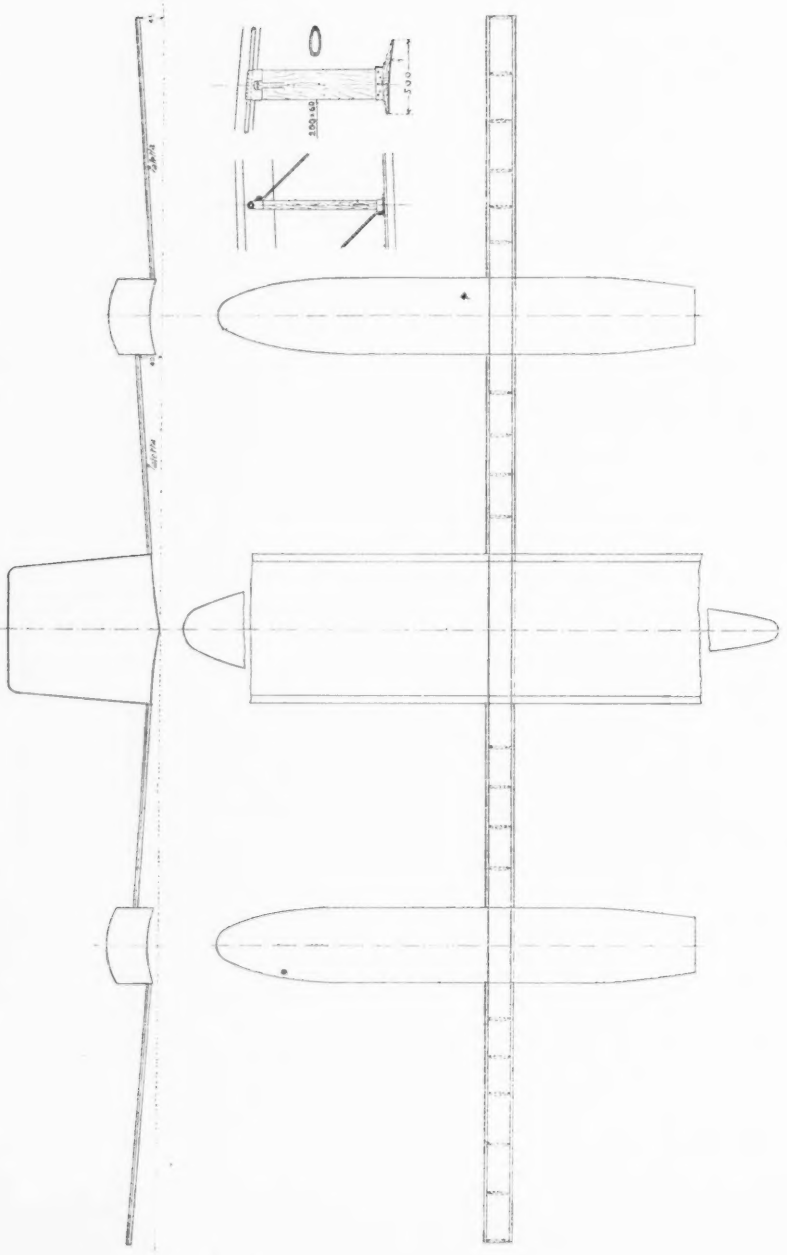


FIG. 15.

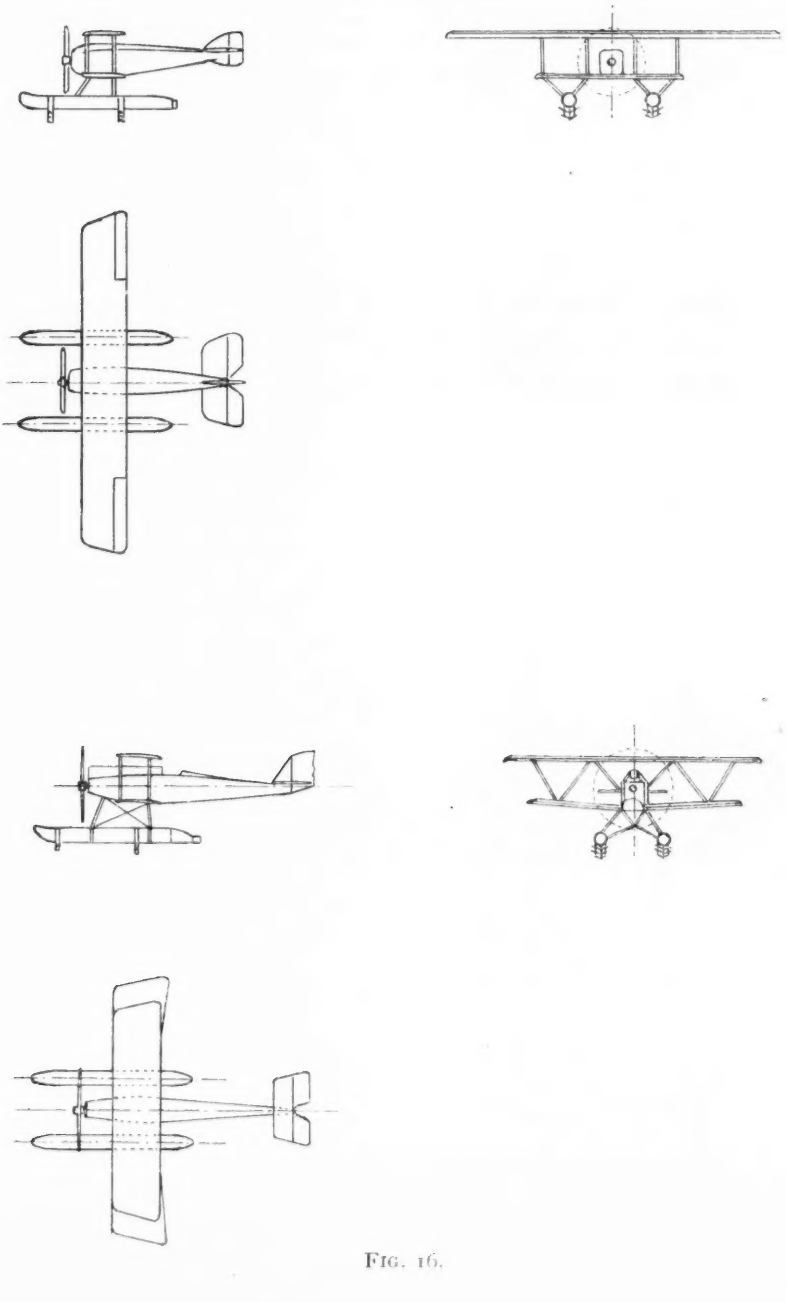


FIG. 16.

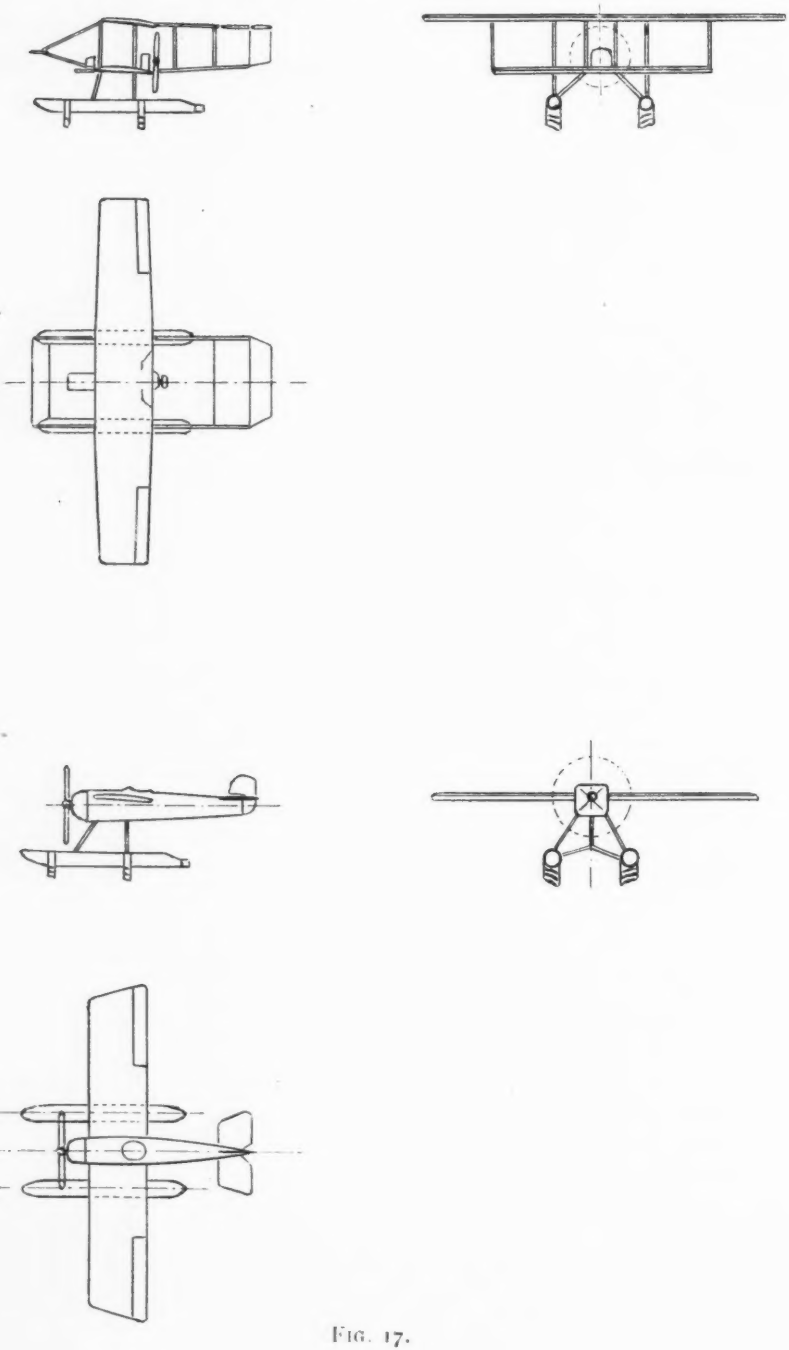


FIG. 17.

Other devices were petrol tanks in aluminium and a release gear of the torpedo. In 1913 I was only able to have the two Gnome 18-cylinder 200 h.p., which proved a very delicate engine.

Tests went on smoothly and I had the satisfaction, in August, 1913, of dropping a dummy torpedo of 700 lbs. without any mishap. Then came the war and this machine was put aside.

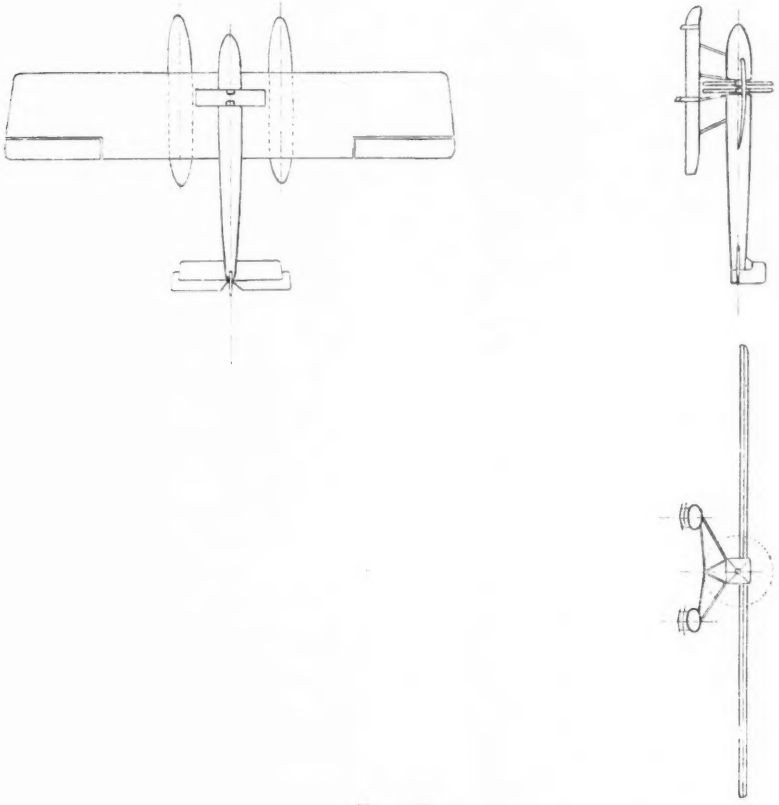


FIG. 18.

About 1917 the S.V.A. seaplane resulted from the adaptation of floats to the well-known S.V.A. used as a fighter at the end of the war.

In this machine the cylindrical part of floats had been built in plywood, with a great saving in hand labour (Figs. 11—17).

Forward and aft vanes in steel blades were ground to shape and proved to be the most economical way for the first stage of labour.

Hydrovaned floats were built in 1918 for the Caproni machines Ca.600 and Ca.T and they were the biggest I ever used (Figs. 13—19—20). They were light and strong. Indeed all longitudinal stresses were supported by the wood planking and frames were only required to maintain floats in shape. The weight

of this kind of float was only 30 Kg./m.^{3} or 6.1 lbs./cu. ft. and they were absolutely reliable and watertight.

The Fiat had built in 1917 a very interesting steel bombing plane with two engines of 600 h.p. and I designed for it three kinds of floats: one cylindrical, of aluminium, and two of a mixed design, in wood (Figs. 14—21).

As the machine was abandoned after the first tests there was no construction of floats, models of which were tested in the tank.

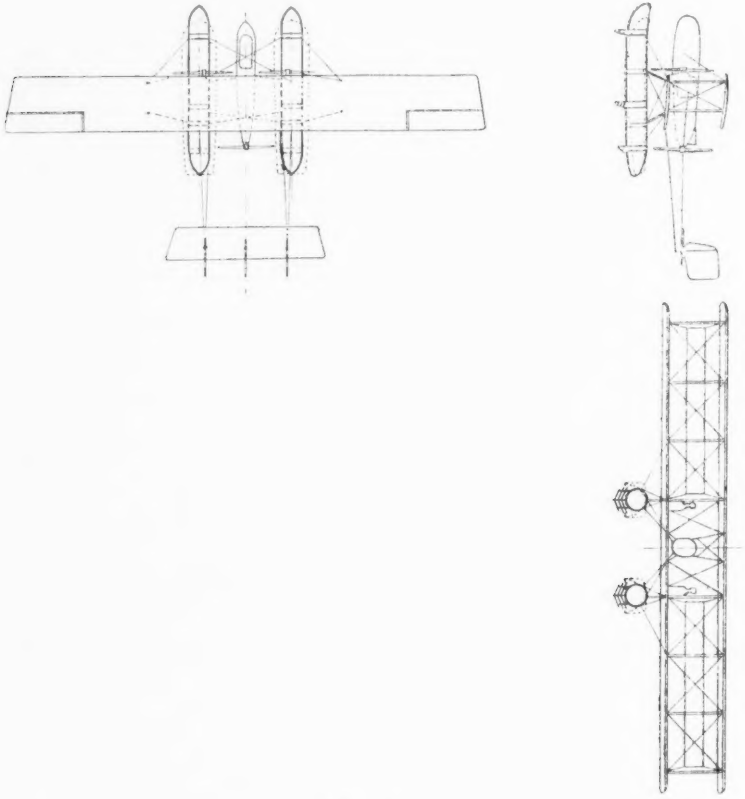


FIG. 19.

After the war, Caproni, who had already the big five-engined triplane, went on with a new 25 tons machine (Ca.TT) and I was asked to design its floats (Figs. 15—22).

Owing to the particular design of the machine, a totally new kind of float and vane was employed, with the aim of reducing the width and weight of the main float.

This was given the size necessary to allow 100 passengers to be comfortably seated, and a 7 ft. by 7 ft. by 75 ft. boat resulted. The necessary hydroplane area was reached by adding two vanes between the main boat and lateral floats, and two extensions outside which tank tests proved to be unnecessary.

At the second test the machine succeeded in taking-off, crashing on landing; although the weight was only 45,000 lbs. it can be assumed that the floating device was quite appropriate. Fig. 7 shows the general arrangements of floats either built or tested as model. Figs. 8—15 are the details of same floats and vanes and Figs. 16—22 show the side view, plan and traversal of the principal machines.

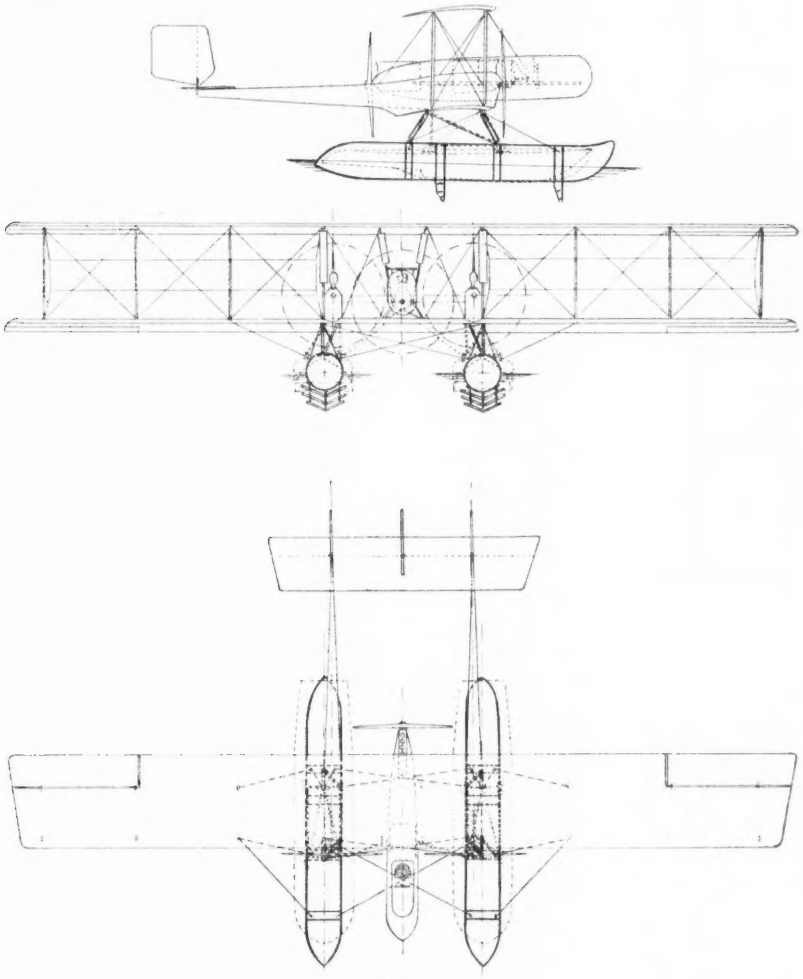


FIG. 20.

The models tests at the Froude's tank gave a valuable aid in all this research work. In Figs. 26—30 are reported some of the results. Comparisons between ordinary and hydrovaned floats, or between vanes of different angle of attack are shown.

In the case of the Ca.TT it is quite surprising how the presence of vanes changes entirely the form of the diagram. In Fig. 31 the gross weight, speed,

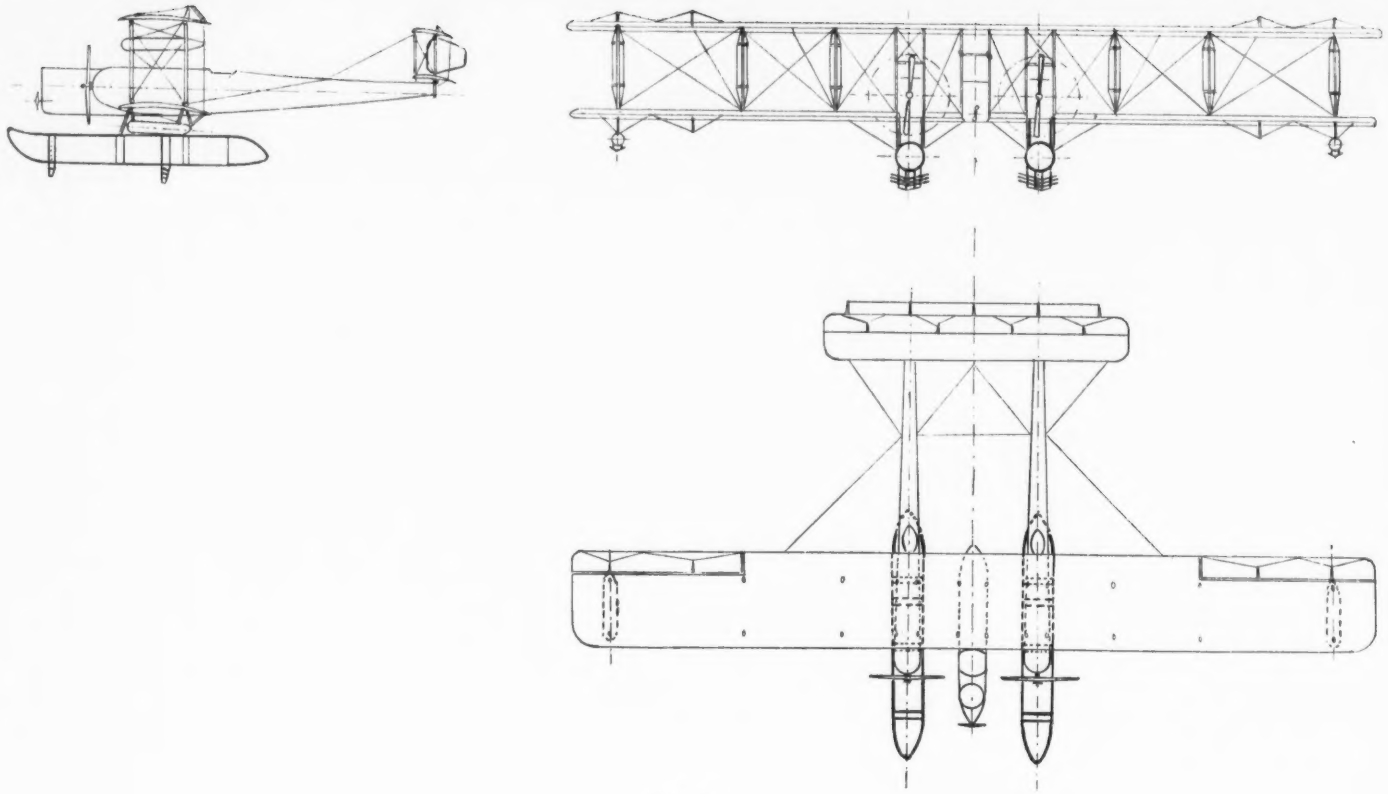


FIG. 21.

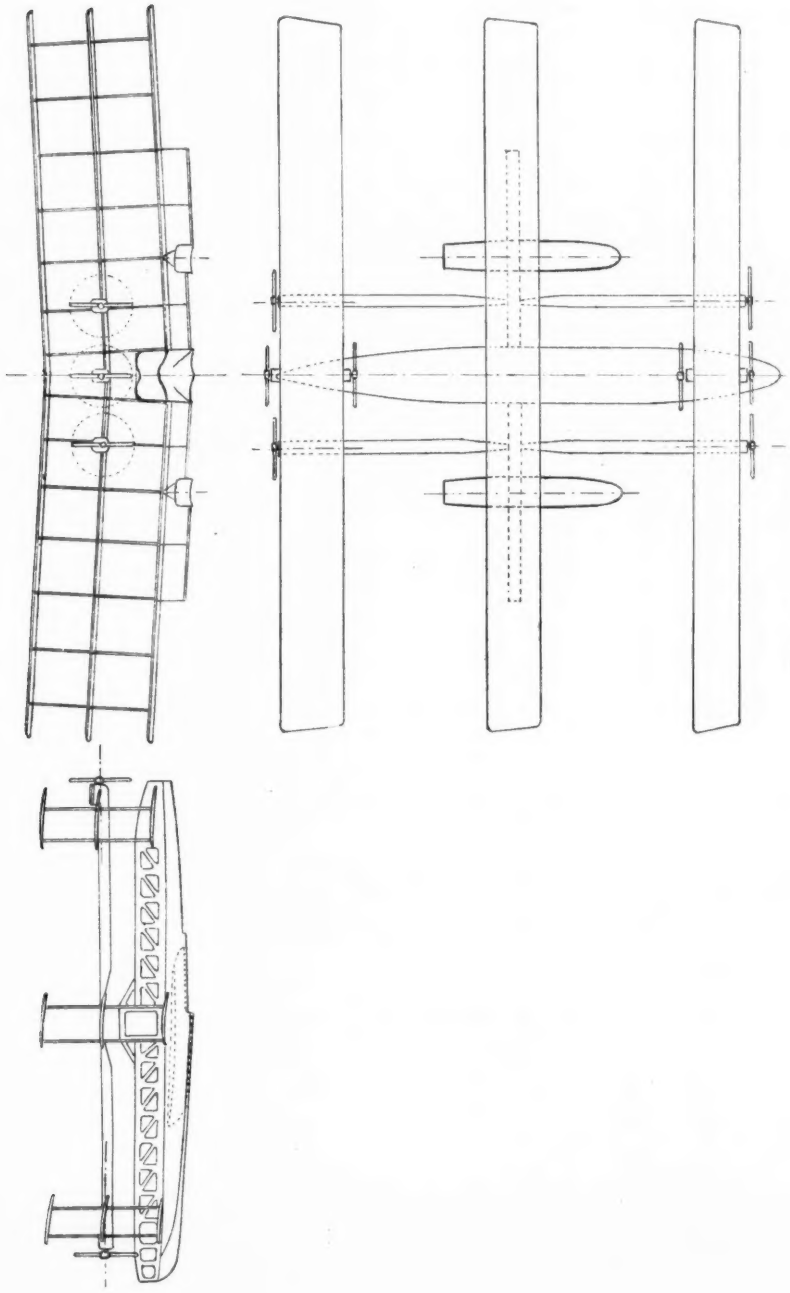


FIG. 22.

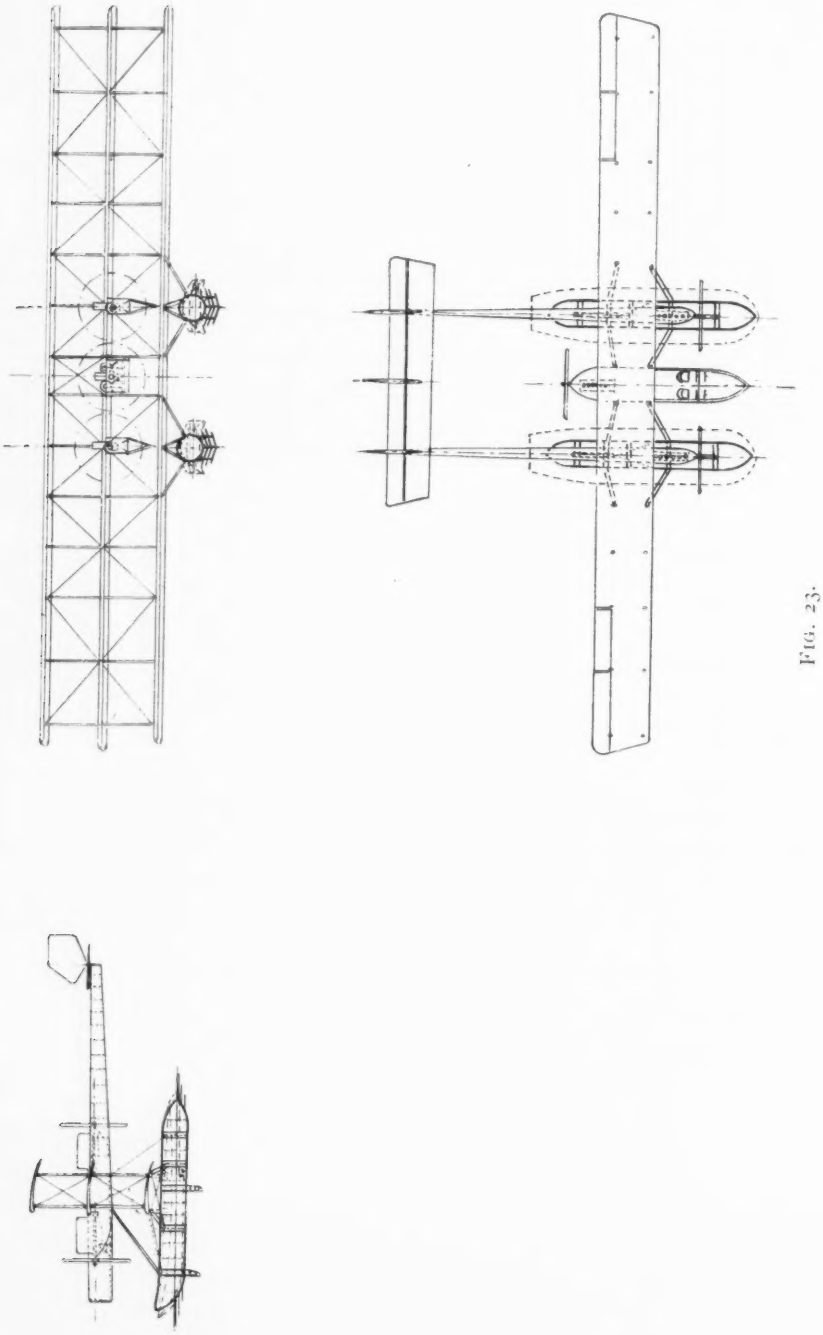


FIG. 23.

weight and volume of floats, weight and area of hydrovanes are given for all the machines recorded in this article.

Except for the Fiat biplane, all others have actually been tested and flown; the Ca.600 and Ca.T had been designed both with ordinary and hydrovaned floats.

In my research, as a matter of fact, I had always the practical point of view as my principal aim. I never thought any theory worth much attention if its practical application were not possible and advantageous.

The Design and Calculation of Hydrovaned Floats

An approximate calculation of vanes and floats can be made on the following lines:—

Known elements are:—

W = total weight of the machine.
h.p. = horse-power.
V_0 = normal speed of flying.
T = thrust of propeller.

Diagrams of weight (3) and air lift (1), propeller thrust (4) and air drag (5) can be traced; then a value V_1 of speed can be chosen corresponding to the instant the floats are leaving water (Fig. 3).

As a first approximation the curve (2) can be calculated, supposing the lift given by the vanes proportional to V^2.

Then going back to diagrams of thrust and drag, it can be calculated the drag of vanes in water (6) and the drag of floats (7).

Formulæ to be used are:—

(1) $ky \cdot S \cdot v^2$ (tunnel tests).
(2) $k'y \cdot \sigma \cdot v^2$ $k'y = 7$ to 5 lbs./sq. ft.
(5) $kx \cdot S \cdot v^2$ (tunnel tests).
(6) $k'x \cdot \sigma \cdot v^2$ $k'x = 1$ to 0.6 lbs./sq. ft.
(7) $k \cdot d^{2/3} v^2$ d = volume of submerged portion of floats.

The maximum value of total drag must result fairly below the thrust curve.

However, if the difference be too exaggerated, this means that the speed V_1 has been chosen too low or that σ, the area of hydrovanes, is too high, or angle of attack not the best.

The diagrams of thrust and drag are very useful to the engineer because the difference between thrust and total drag gives the inertia force available and therefore the acceleration of machine at the start and it is possible to find the time and distance required in taking-off.

Shape of Floats

In regard to curve (7), the use of the Admiralty formula gives a very rough approximation, as the submerged section of floats varies as the speed increases. This is another point which makes this calculation not so precise, but it must be noted that the drag of floats is not very important when vanes are employed.

The worst shape of floats can easily be overcome by a little increase in hydrovanes. For small machines the cylindrical or streamlined form is the best one.

Area, Angle of Attack and Form of Hydrovanes

The tank model tests are quite useful for new machines, in order not only to find out the drag, but in giving the hydrovanes the correct size, form and angle of attack.

Varying the area, the aerofoil of vanes and the angle of attack, different values of k'_y and k'_x must be assumed, if the design is made by calculation. Increasing the area of hydrovanes has the effect of reducing both the maximum value of drag and the critical speed; but this not indefinitively, not only because of the reason we have seen in the theory, but also because the increase of vanes means an increase of weight, and on the other hand, if the machine is supported

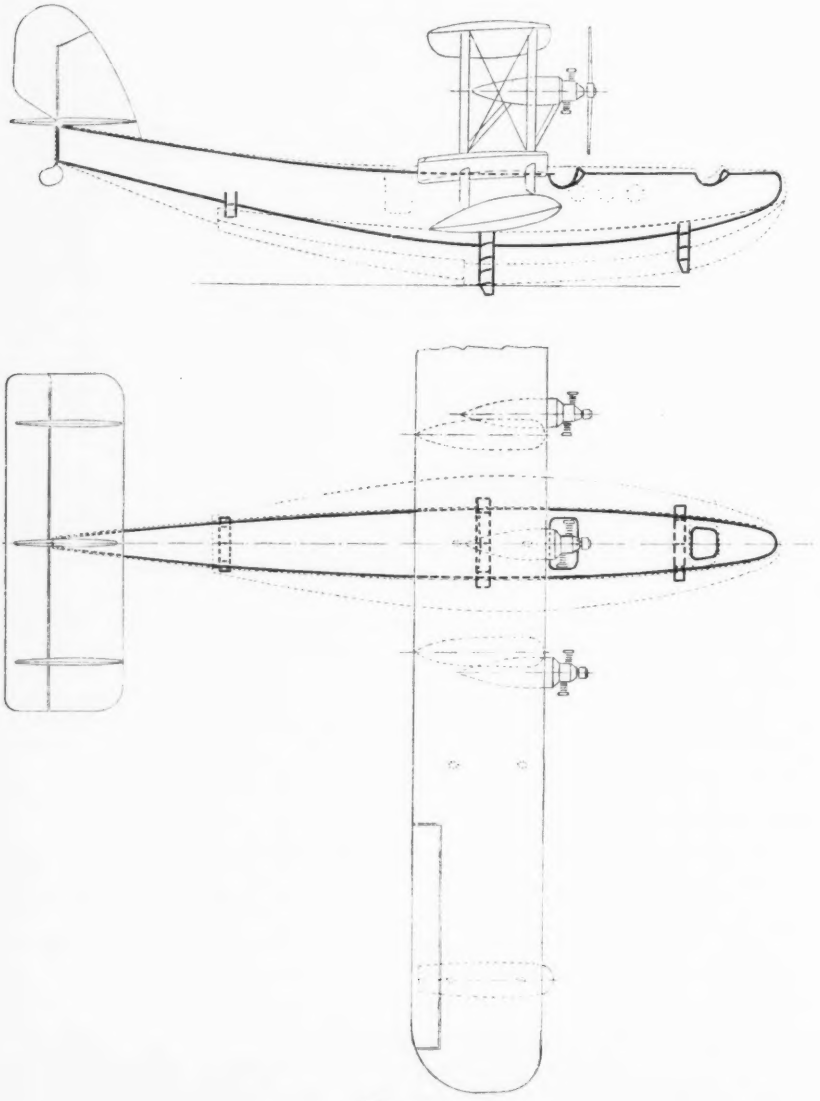


FIG. 24.

only by the hydrovanes at very low speed, it is not easy to control, as the ailerons and rudder have little effect if any at that speed.

It is therefore preferable not to exaggerate in hydrovanes, and after having calculated the optimum area increase its value by a reasonable quantity.

The importance of a good aerofoil of the right size and shape can never be emphasised too much. These small surfaces are sometimes cutting the water at 50/60 m.p.h., so these elements are much more important than for the wings of an aeroplane; the problem is far more difficult than that of wings of a racing aircraft and must be thought out very carefully. Many negative results which have hindered the adoption of hydrovaned floats can be put down to the wrong shape and wrong aerofoil of the lower vanes, which are the most important.

The increase of the angle of attack gives an increased lift, but also an increased drag of vanes. As can be seen from Fig. 29, the total drag is much less with 6° of angle of attack than with 12°.

Theoretically the angle of attack, for which L/D has the maximum value, should be chosen, but practically it is impossible to do so in many cases, because supposing the best angle of attack to be 2°, it would be very easy both in taking-off or in alighting to have this vane attacking the water negatively with very bad consequences.

When the use of a tank is possible, as already said, it is much easier to get the correct design. The only drawback of this system is the difficulty in reproducing the air lift and drag of the aircraft and their influence on those of the floats. It has been found necessary to connect the model of the floats with an aerofoil which reproduces the air lift and drag of machine.

Another important point is the scale of the model. Supposing an aircraft flies at 120 m.p.h. in the air, its model would be on the scale of 1/72, because the speed in the tank cannot be over 14 m.p.h. At this scale forces are very small and it is quite impossible to limit the weight as imposed by the similitude

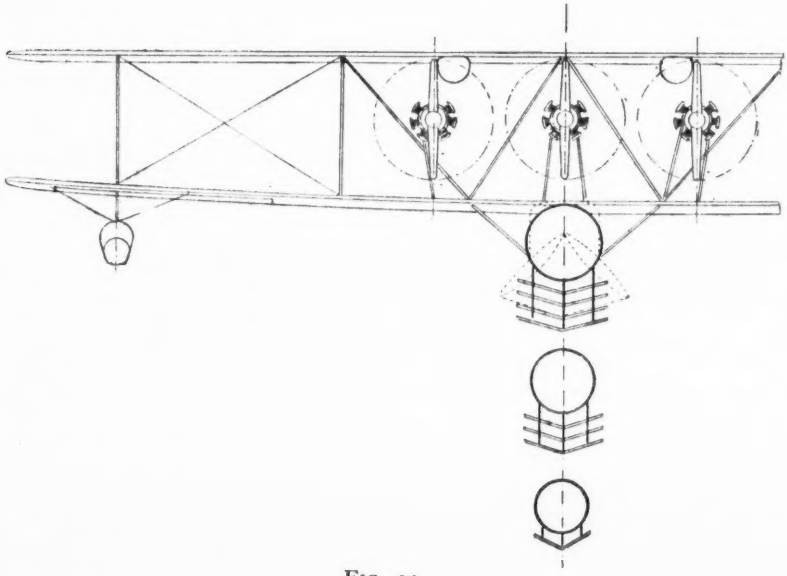


FIG. 24.

law. For instance, if weight is 8,000 lbs., the weight of the model would be only 8,000/373.248 lbs. = 0.021 lbs.

With the present tanks it is therefore impossible to extend the tests till the flying speed V_0 is reached; the scale of models must be between 1/5—1/15 which on the other hand is quite sufficient to cover the phenomenon well over the critical speeds V_1 and V.

The practical rules I found during my tests can be stated as follows:—

The area of hydrovanes depends upon the weight of the machine, the critical speed and the power of the engine.

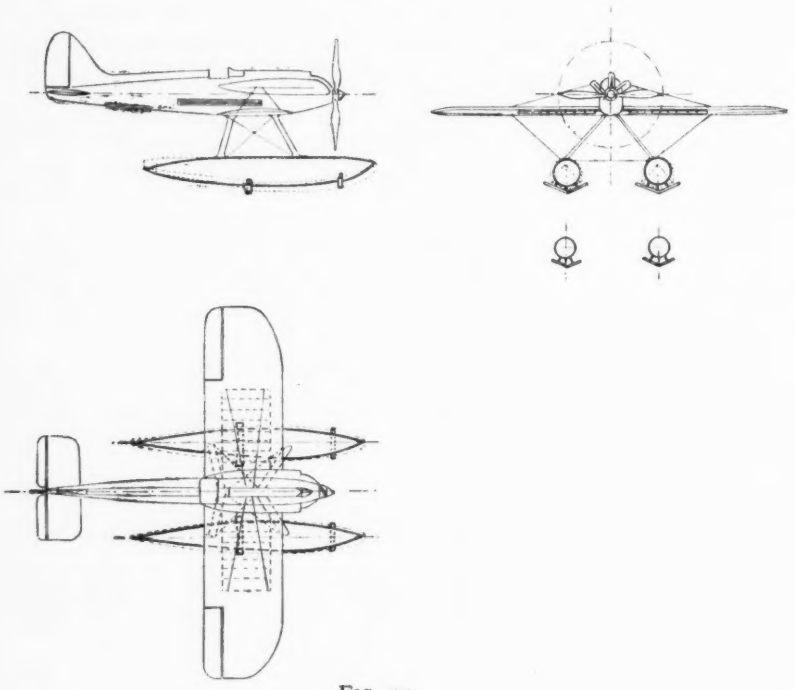


FIG. 25.

Hydrovanes may be concentrated in one set or two sets. In the first case the position of vanes is exactly that of the wheels of the ordinary undercarriage (B.1, Fig. 7). Control of the machine is not very easy. I had only one test in this case and although everything went all right, I do not think it advisable to adopt it. Both taking-off and landing require the close attention of the pilot. The area must be reduced at a minimum in order that the critical speed may be as high as possible, allowing for a good air control of the machine. When properly handled, the taking-off is certainly easier, it being possible to give the hydrovanes the best angle of attack.

The second case, where two sets of vanes are used, presents no difficulties. The first set must be well forward of the C. of G. and the second one a little back of this point. The first one must be about one-third of the total area. The depth of the first set must be less than that of the second one. These elements vary according to the size of the machine.

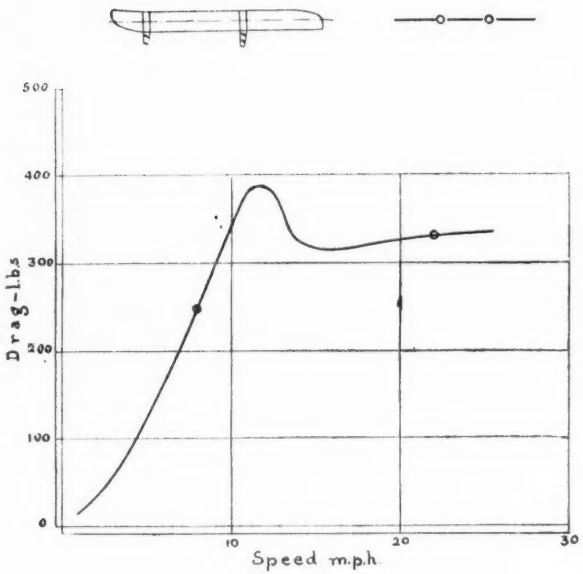

500
400
300
200
100
0
Drag-lbs
10
20
30
Speed m.p.h.

FIG. 26.

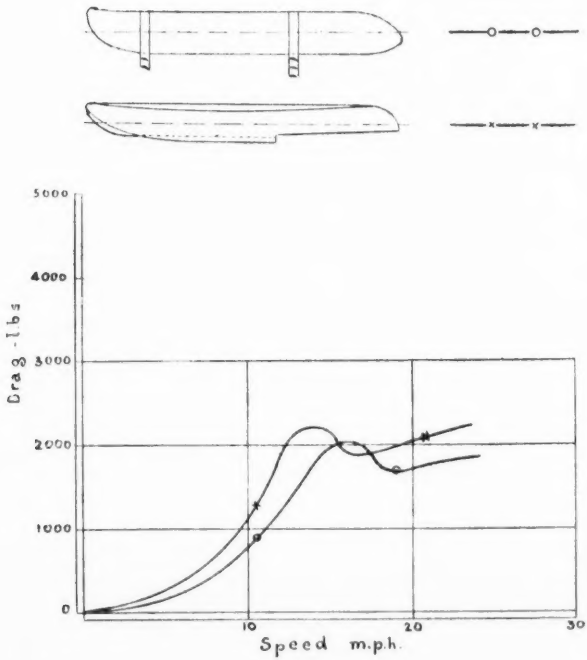

5000
4000
3000
2000
1000
0
Drag-lbs
10
20
30
Speed m.p.h.

FIG. 27.

This arrangement ensures a hydrodynamic support well forward when the engine is started and in the first moments of motion, thus preventing the nose of the aircraft dipping into the water. At a very low speed the forward vanes emerge from the water and the lift passes gradually aft till it is taken only by the lowest one of the second set.

The difference in depth is necessary at the moment of getting off, to permit a longitudinal balance of the machine taking place, so that the pilot can vary the angle of attack of his wings and take-off at the moment he thinks advisable. The greater the depth of vanes the better for landing or taking-off in rough sea.

The area and angle of attack of the vanes should decrease from the top to the bottom, because at the first period of motion the thrust of the propeller is greater than the total drag, so the only aim is to have the maximum lift, in order that the floats may clear the water as soon as possible.

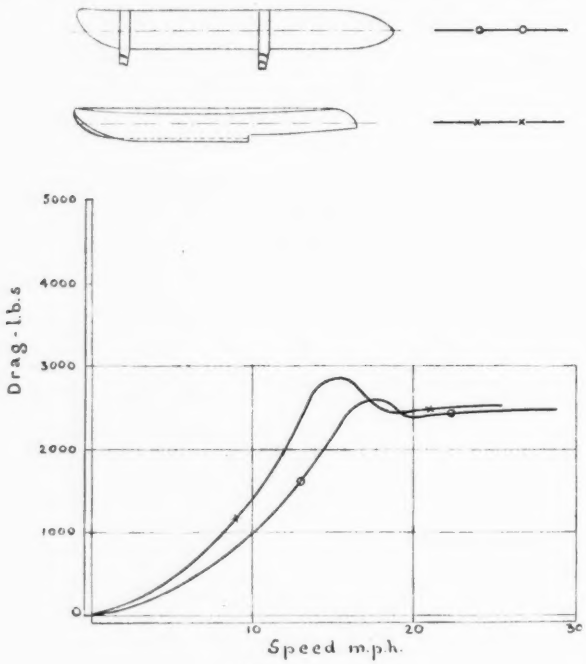


FIG. 28.

In the last stages it is very important that the vane has the best aerofoil design and the optimum angle of attack in order that the drag may be a minimum.

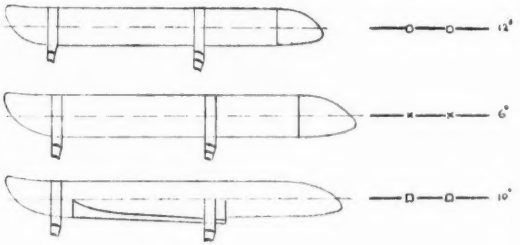
For the upper vanes of the fore set, angle of attack can be of 12°; 8° for the lower one. In the aft set angle should vary from 6° to 3°.

To avoid swerving in the water, especially at high speed, vertical fins must protrude from the vanes. In some cases it is necessary to have a vertical fin at the aft end of the floats. Swerving of the machine, especially with a two-floats seaplane, is quite a common experience and must be dealt with.

Weight referred to area of vanes should vary from 800 to 300 lbs. per sq. ft., 500 lbs. per sq. ft. being a good practical value. The upper vanes can be of

duralumin, the lower of steel, especially in fast machines. The fore set can be straight, but the aft should be a V in order to avoid any twist on floats.

For small and powerful machines, streamlined floats and V-shaped hydrovanes are the best. But when the gross weight of the machines is over 3,000 or 4,000 lbs., it is advantageous to have a flat bottom and redan, in order to decrease the area of hydrovanes. But where hydrovanes are indispensable is when the weight is over a certain limit.



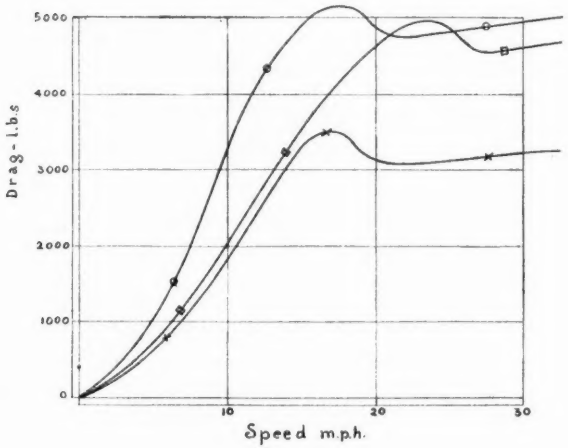


FIG. 29.

Indeed it can be accepted that at a certain approximation the hydroplane area of the ordinary float increases at the index one of weight. Thus, if a seaplane of 4,000 lbs. needs 9 sq. ft. and a redan of 5 ft., one of 40,000 would need one of 90 sq. ft. with a redan of 16 ft. The lengths of the boats should be 36 ft. and 100 ft. So for a seaplane of 40,000 lbs. one should provide a boat of 100 ft. by 16 ft., weighing thirty times that of the 4,000 lbs. plane, instead of ten times, as it would be logically expected.

While the effects of this law are not so important when the weight is only moderately increased, its bearings are quite unexpected when one reaches very big displacements.

The increase of hydroplane area may be reached by lateral bulges or expansions as in the Short and Dornier boats but, as stated before, this proves quite insufficient when great weights are dealt with.

Hydrovanes afford quite an easy solution to this problem. Either they are just under the floats for displacements up to 15,000 lbs. or lateral hydrovanes are used up to 40,000 lbs.

The triplane Caproni, which is one of the largest seaplanes which has been in the air, although for a few minutes only, had a boat of only 7 ft. width with two lateral wings of 2 ft. by 15 ft., which proved enough to give the necessary lift.

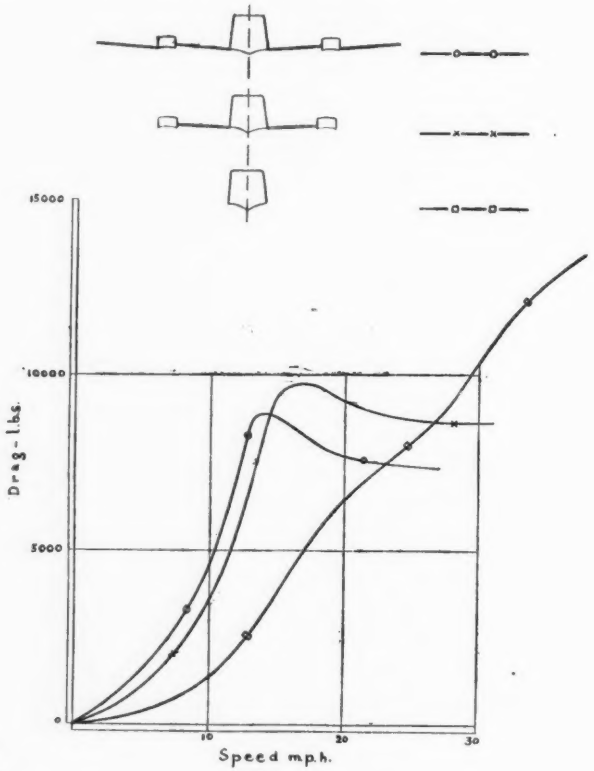


FIG. 30.

Indeed this area can be considered very small, but in reality it is not so, because it is all useful hydroplane area, whilst an ordinary boat bottom has only a strip used as hydroplane area.

Advantages and Inconveniences of Hydrovanes

In the many years the tests were going on I could find many advantages for this system. The disadvantages of an ordinary boat are:—

The increased depth; the ease with which grass and other floating remains can be caught up in the vanes, causing braking and making it impossible to

take-off; the difficulty of being fixed on an under-carriage and raised. In the case of fast machines, which take-off at a very high speed, the aerofoil of the bottom vanes requires a careful study and especially its angle of attack in its relation to the angle of attack of main surfaces.

Indeed, whilst there is no difficulty for the design of vanes for a slow machine flying at 100 m.p.h., it is very easy to meet with a failure in case of fast machines and the design of floats and vanes requires there theoretical research and both air tunnel and tank tests.

Advantages are:—

Economy in weight, owing to the fact that floats are only for static support and do not strike the water until the speed has slowed down, so the structure can be lighter than in the ordinary case.

The possibility of giving the floats a good aerodynamical or streamlined shape, so reducing the air drag.

		Gross weight lbs.	H.P.	Speed m.p.h.	Weight of floats lbs.	Volume of floats c. feet.	Weight of hydrovans lbs.	Area of hydrovans sq. feet.
1	F_1-F_2-F_3	1400	60	56	132	40	30	5.3
2	N	1500	70	70	135	45	32	5.0
3	B-B_1	1700	70	62	140	60	35	4.8
4	C.A.	2000	100	80	135	65	40	4.6
5	S.V.A.	2600	220	130	167	70	88	8.5
6	P.G.	7500	380	65	660	270	300	22.
7	Ca. 600	8700	900	90	750	390	350	27.5
8	Ca. T.	13200	1200	80	1100	550	450	35.
9	F.I.A.T.*	17600	1300	100	1200	600	500	38.
10	Ca. T.T.	55000	3200	90	11000	3800	600	70.

* This machine only has not been actually flown.

FIG. 31.

Landing a machine also in a rough sea is easier. In taking-off, no bumps or shocks of any kind are experienced, the machine behaving as if it were supplied with the most efficient of shock absorbers. This is to me the most important of the various advantages.

The hydrovanes may have a proper aerofoil section for the various stages of taking-off, so the drag in water is reduced to a minimum. This is quite important in the last moment of the course on the water. The air drag of a hydrovaned float is less than that of an ordinary float, and in the same time a lift is developed by hydrovanes which to a certain extent compensates their weight.

There is no possibility of the machine assuming in the water a stalling position, as frequently happens with other floats. The machine has only a very small angle of longitudinal inclination in the first stage; when the boats are free of the water she can be easily controlled by the elevators. No lateral control is required in taking-off as for an ordinary flying boat.

Some Practical Applications

Fig. 23 gives a comparison between an old seaplane, the Ca.600, fitted with ordinary floats and one of the same type fitted with vaned floats. Two examples of use of hydrovanes in the design of some present seaplanes are in Figs. 24, 25.

The first is a large cruising flying boat with three engines, where the normal boat has been substituted by a smaller one with two hydrovanes sets. The volume of the boat is still twice the displacement, which is a quite safe proportion for all the necessity of a seafaring craft. The weight of the hull and hydrovanes is certainly less than that of the present boat and also the air drag is less.

Indeed not only the volume has been decreased, but the strength of the structure may be much smaller, because when speed has reached twenty knots the boat is already out of the water and so it has not to encounter the big stresses of the ordinary boats.

The second example is a racing seaplane where usual floats have been changed to streamlined ones. In a seaplane of this kind, which is landing and taking-off at a speed over 110 m.p.h., I think the use of hydrovanes would be a certain improvement both in reducing the head resistance and giving the pilots almost entire security and safety, both in landing and in taking-off.

It must be stated that it is almost impossible to have a mishap in landing when hydrovanes are provided. Being myself a pilot and an engineer, I could fly my own machines and, although some minor accidents occurred in the tests, I enjoyed them very much and they are my best recollection of past years.

Ending this résumé, I must say that it has been impossible to incorporate all dates and results in this article, but they are at the disposal of anyone who would be interested in the question.

ARE AERO ENGINES RELIABLE?

An Informal Discussion and Dinner was held on the 15th November, 1927. The Dinner took place at the Royal Aero Club, who courteously gave the Society permission to use the Club that night and made every possible effort to make the Dinner a great success.

The Chair was taken by Colonel the Master of Sempill and the subject for discussion was "Are Aero Engines Reliable"? Mr. FOORD in opening the discussion said that the balance of evidence was in favour of reliability. The average motor car ran for 20 to 30 thousand miles between overhauls while locomotives ran between 50 and 60 thousand miles between overhauls. He had looked into the average overhaul figures for all types of aero engines, both those that were modern and those that were obsolescent, and he found that the time between overhauls in the modern engine came to somewhere about 90 thousand miles and was 20 thousand miles in the worst of the old types, while an average for modern engines was somewhere about 50 thousand miles. This seemed to show that the aero engine was was quite as reliable as the motor car engine or the locomotive. There was no doubt about it that most of the failures were not engine failures at all, but failures due to installation for which the engine received the blame, and the percentage of failures in water-cooled engines was considerably higher than that for air-cooled engines. Much of this trouble could be obviated if there was co-operation between the engine and machine designers. The engine designer should control everything to do with the engine including its installation. He hoped to see in the future that the water and ignition systems could be eliminated. There was one other point which led to the apparent unreliability of some engines and that is that they were often used for jobs for which they were not intended.

Mr. CHORLTON said that long life could not be taken as a sign for reliability, for on that basis the Beam engine was the most reliable of all engines, as he had known Beam engines in use for over a hundred years. The real criterion was heat capacity and the aero engine was rated at least twice as high as any other engine in its heat capacity. The real blame for the unreliability of engines lay with the constructor, who demanded lighter and lighter engines and greater and greater power. The compression ignition engine used less heat than the petrol engine and was, therefore, more reliable.

Mr. HANDLEY PAGE said that most people thought reliability meant infallibility. That was not true. He believed that there should be a number of engine units placed in the wings. He thought at the moment, that engine design was ahead of the constructor and that the latter should design machines which would require less power to drive them. Constructors should take the engine as it exists to-day and not keep looking forward to some super engine of the future.

Major CARTER was of the opinion that many engine failures were due to crankshaft vibration and it was necessary to solve this problem before the engine could be made absolutely reliable, though on the whole he thought that the reliability of engines was remarkably good.

Colonel FELL stated that engines were nothing like as reliable as they might be. The failures in most cases were due to details, inexperience of maintenance and defects in designs. There was no doubt that engines would improve as they had longer development. As a matter of fact, one of the most reliable engines at present is one designed at the beginning of the war and it is remarkable because it has had the longest development. Lightness in design did not tend

to unreliability, and in fact, an engine had been built weighing only $\frac{3}{4}$lb. per horse-power; its life was stated to be only one hour but in actual fact it ran 20 hours with no signs of wear whatever. We were rather in the position of the locomotive designer of 1840. At that time it was considered that a locomotive boiler, which lasted for 20 thousand miles, was a good boiler but now locomotive boilers run for over 250 thousand miles before they want overhauling. When we have had longer experience of developing aero engines we shall certainly get better results. The reliability of the aero engines has gone up four times since the war and during the next five years he expected it to increase in the same proportion.

Captain WILKINSON thought progress had been immensely rapid on engines. He pointed out that in 17 civil aviation engines, of which he had knowledge, the average time between overhauls was 290 hours, or about 30 thousand miles, and the daily maintenance was extremely small. He did not agree with Mr. Chorlton that the drop of the mean effective pressure increased reliability. The dropping of the mean effective pressure increases the heat flow, while the raising of the mean effective pressure lowers the heat flow and so brings greater reliability.

Mr. FEDDEN considered that engines could be improved if close attention was paid to certain points. The first was the question of lightness, which calls for a great amount of thought in engine development as it left such a very small margin of safety. He believed that if the weight could be slightly increased the reliability could be increased to a very much greater extent. Another difficulty which he found was that of obtaining clean steel and reliable materials generally. He thought that an engine design should not be changed for at least eight years and much more research should be given to the question of obtaining materials suitable for engine construction. The present small output led to increased costs and wasted experiment, and he thought that when there was greater demand for engines there would be much more research made on the material side and this would lead to greater efficiency. He agreed with other speakers that one of the great causes of engine failures was due to installation.

Mr. WIMPERIS pointed out that reliability might be defined as uniformity of performance, and in that case in a way the aero engine was not as reliable as it might be. Tests which have been carried out with identical engines in identical conditions showed that they varied as much as 20 per cent. in their fuel consumption, and if this 20 per cent. variation could be eliminated as much as £100,000 a year could be saved in the R.A.F. alone.

Wing Commander CAVE-BROWNE-CAVE said that he looked upon reliability as freedom from unexpected failure. He wanted to press home that the power plant should be tested as a whole. At the present time the engine underwent a type test and he thought that the engine with its installation and so on should undergo a similar test. There was no doubt that the installation was one of the great causes of the trouble.

Mr. HERON said that the aircraft engine could be considerably improved but he considered that the advances which have been made during the last 10 years were remarkable. He agreed with Mr. Fedden that the future of the aeroplane engine lay with the maker of materials and every effort should be made to carry out tests in connection with the materials for engine construction.

Major BULMAN thought engines were reliable and in a particular series of four engines which had been thoroughly overhauled after 260 hours running all that was necessary to replace was one gas ring and one scraper ring. The reliability depended on care of manufacture. He agreed with Mr. Fedden that castings should be replaced with drop forgings as soon as possible. As regards the variance in apparent consumption of similar engines under similar conditions, he thought the fault lay with the petrol flow-meter which did not register properly,

and the blame should lie upon the instrument designer and not upon the engine designer.

Mr. TIZARD was uncertain what was the best form of comparison between aero and other engines. If one considered weight per horsepower there was no doubt that the human being was as efficient an engine as anything that had been made by man as it was very reliable and lasted a lifetime. After that he would be inclined to place the London motor-bus. The aero engine certainly does not compare with the motor-bus engine for reliability. He agreed with other speakers that more attention should be paid to materials, and we could afford in an engine to use much more expensive materials than we are using without adding very much to the cost of the engine. As an example at the present time, the cost of materials was about 8d. per pound, while the cost of an engine was about 30/- per pound, so we could easily afford to use materials costing three times as much and only adding somewhere about 1/6 per pound to the total engine cost.

Captain SAYERS drew a comparison between the aero engine and the commercial engines such as used in electric supply works. In most commercial undertakings other engines were provided at least in duplicate so as to avoid a failure, and a new engine could be switched on and electric light customers would not know there had been any breakdown at all. The same thing should happen with aeroplanes. There should be a number of engine units so that the failure of one did not cause a forced landing. There was no doubt that aero engines were far more reliable than other engines of ten times their weight per horse-power, and that in spite of the fact we were working on such a small margin. There was no doubt that a greater part of the so-called engine failures were really failures in the installation, and he agreed with Commander Cave that there should be tests with the installation or for the power plant as a whole in the same way as there was at present a type test for the engine itself. The engine designer should be made responsible for the installation.

Major KENNEDY strongly supported Mr. Chorlton that the fault lay with the aeroplane constructor. The latter was calling for lightness more and more. If they looked back they would find that in all forms of transport lightness was called for in the early days, and there was a craze for making all kinds of engine lighter and lighter. Gradually it was realised that this was no good. He was of the opinion that the time had come to make a strong protest against decreasing the weight of an aero engine and there must come a time when it will be found wiser to add to the weight rather than to lessen it and so force the aeroplane constructor to build machines which were more efficient and used less power. There was no doubt that in the future the variable pitch airscrew would solve many problems now facing the engine designer, for such a screw combines the advantages of a gear box and a clutch in one, and enables an engine to take up its load gradually as the clutch and the gear box in motor car do now.

Captain IRVING in summing up the discussion said he rather agreed that the constructor was to some extent to blame for demanding a light engine with high mean effective pressure. On the whole, however, the majority of troubles were due to installation, and he said that flying in a commercial machine a few days before he had noticed that the vibration on one of the water pipes was so severe that the pipe completely disappeared and it could only be a matter of a very short time before it would break, and so cause failure which would be blamed unjustly on the engine. An engine designer should follow up his engine and see it properly installed, and be, in fact, responsible for the installation. The water-cooled engine caused a great deal more trouble than the air-cooled engine. He agreed with Mr. Tizard that the London omnibus was the most efficient transport vehicle in the world. It ran for 40 thousand miles between overhauls and gave 20 ton miles per gallon. The modern five-seater motor

running at 20 miles per gallon, only reached a figure of seven ton miles per gallon, while an aeroplane only reached a figure of two ton miles per gallon, so that there was room for considerable improvement in the aeroplane as a form of transport.

CORRESPONDENCE

To the Editor of the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

DEAR SIR,—It is not realised so generally as the fact may be deemed to deserve, that the centenary of the death of James Sadler, the "First English Aeronaut," falls on March 27th of next year. Sadler was the first Englishman to ascend into the air in a balloon, of which (to adopt Cavallo's words) he was not only "the sole projector, architect, workman, and chymist," but pilot to boot. He was also the first English balloonist to make considerable flights through what Cayley finely called, "that uninterrupted navigable ocean which comes to the threshold of every man's door." If his aerial flights were perforce accomplished in an aeronautical machine that has now passed into obsolescence, he deserves not the less some measure of that immortality conferred by Horace on the sailor who, with threefold courage, first "adventured to sail upon the sea."

But the state of hopeless decay into which Sadler's tombstone in the churchyard of St. Peter's at Oxford has been allowed to fall, is significant of the general attitude of indifference towards his memory. As to the tombstone, the Royal Aeronautical Society undertook, some months back, to bear the cost of restoration, which will shortly be done. But it is felt by some that a small memorial in the form of a tablet of stone or wood, might justly and fittingly be placed in the church of St. Peter's as a tribute to his memory on the centenary of his death. The project has the support of Mr. Harold Sadler, the grandson of the aeronaut's son, Windham Sadler (himself an aeronaut, who was killed in a ballooning accident in 1824); of Mr. Henry Sadler Alford, a great-great-grandson of James Sadler; Major B. F. S. Baden-Powell, a former President of the Aeronautical Society, and an experienced balloonist; Colonel the Master of Sempill; Lieut.-Colonel Lockwood Marsh, and others. To carry out the idea it will be necessary to raise the moderate sum of £50 or so, of which about £10 has been already promised.

May I be allowed, through the columns of our JOURNAL, to invite further subscriptions—which may be addressed to me at Albemarle Street—in order to ensure this belated tribute to the Englishman who, animated by the same spirit that has long since become a tradition amongst all British pilots and sailors on the sea, first dared to demonstrate to his countrymen the possibilities that lay in the navigation of the air.

Yours truly,

115, Chancery Lane, W.C.2.
December 6th, 1927.

J. E. HODGSON,
Hon. Librarian

P.S.—May I add that on merely mentioning the matter quite incidentally to an aeronautical friend in New York, he promptly and generously wrote asking to be allowed to contribute and enclosed a draft for ten dollars.

BRANCH NOTICES

YEOVIL BRANCH

The above Society has now been in existence for just over one year, and during the last winter session 27 lectures were delivered.

The Officers and Committee of the Society are as follows :—

President.—R. A. Bruce, Esq., M.I.M.E., M.Inst.C.E., M.Sc., A.F.R.Ae.S., etc., Managing Director of Westland Aircraft Works (Petters Ltd.).
Secretary.—Mr. V. S. Gaunt, A.R.Ae.S., A.M.I.Ae.E.
Assistant Secretary.—Mr. H. J. Penrose, A.F.R.Ae.S.
Committee.—Messrs. A. S. Keep, B.Sc., A.F.R.Ae.S.; A. Davenport, A.F.R.Ae.S.; Captain G. T. R. Hill, M.C., M.Sc., F.R.Ae.S.; W. G. Gibson, A.R.Ae.S.; H. A. Mettram, M.A., A.F.R.Ae.S.; R. C. Taylor, A.F.R.Ae.S.; H. B. Dalwood; A. G. Goswell; J. A. McLean.

The following are Vice-Presidents :—

Sir E. W. Petter, Kt., M.I.Mech.E.; Ald. P. W. Petter, J.P., M.I.Mech.E.; G. B. Petter, Esq., A.R.C.S.; J. Vincent, Esq.; Capt. R. C. Petter; R. J. Norton, Esq.; E. M. Benjamin, Esq., F.C.I.S.; F. W. Cole, Esq.; A. J. Croft, Esq.

For the coming session lectures have been arranged to be held at approximately weekly intervals.

ALLOY AND STAINLESS STEELS

Paper read before the above Society at the 14th Meeting for Prospective Ground Engineers. (Abridged.)

BY J. HOPCRAFT (OF MESSRS. FIRTH AND SONS, SHEFFIELD).

General Considerations

Steels are divided into two classes—straight or plain carbon and special or alloy steels. The former differ from the latter, the iron having more or less iron carbide (iron and carbon) and containing elements, manganese, sulphur, phosphorus and silicon; while special steels in addition have an appreciable percentage of nickel chromium, vanadium tungsten, etc.

For aircraft steels especially absolute reliability and an absence of failure is required by the constructor. It is clear, therefore, that perfect homogeneity of the final product, brought about by meticulous care in manufacture, from the melting furnace to the finished rolled bar, is imperative. Steel must be completely de-oxidised in melting operations and cast under proper conditions into ingot moulds of best design, re-heated and worked under the best technical control. High properties, as shown by mechanical testing, are of no use if defects and lack of homogeneity occur in sheet and bar.

Furnaces

It is not essential to make alloy steels in the electric furnace; in fact, in general practice throughout the trade it is the reverse, that is to say, more

alloy steels are made in the acid open hearth than in the electric. From my standpoint the following are the main advantages of the electric furnace.

Generally speaking, acid Siemens furnaces are of such a large capacity that the length of time taken in teeming a large quantity of small ingots would be such that the temperature of teeming between the first and the last ingot would vary to a very considerable extent, and it is all important that the casting temperature of ingots should remain within close limits. In order to get over this difficulty, larger ingots are usually cast from the large furnaces. This is detrimental for steels for particular purposes like aircraft, as the larger the ingot the more pronounced is the segregation in the centre. Another advantage with the electric furnace is that one can produce readily material of a purer nature, *i.e.*, more free from sulphur and phosphorus, due to the fact that the material in the molten condition does not come in contact with any contaminating gases, such as is the case in a gas melting furnace. One can also control the analysis of the material to within finer limits, again due to the fact of not coming in contact with a carbon atmosphere.

Faults

During the casting of all alloy steels containing, say, about ½ per cent. of chrome and over, what in the trade is called "kish" is formed. This leaves the ingot surface in a rough condition and in many cases with small laps, and we, in order to remove any fear of such occurring in the final finished bar, either machine the ingot before forging, or forge and roll into a bar about 8in. diameter and then rough turn it before the final rolling or forging. Even this precaution does not definitely remove all fear of slight surface blemishes in the bar, and therefore between each hot working operation the billets are most carefully examined and any minute defects removed by chipping or grinding, for if any such defects as roaks, etc., which originate from the ingot surfaces, remain in the round bar, these, owing to the stresses set up during the hardening, are very liable to extend, and are of such a fine nature that it is difficult to find them until the bar is machined at the user's works, which not only condemns the steel itself but wastes the very often heavy cost of the machining operations up to the time the defect is found. This, moreover, disorganises production methods in the user's works.

Precautions

In order that every precaution shall be taken throughout the works with aircraft steels, a certificate has to be signed and forwarded by the foreman who is directly in charge of each operation. These certificates are to the effect that the operation in question has been correctly performed and that no defects which would render the steel unsuitable for aircraft uses have become evident in the process. All such certificates are co-ordinated and brought to the works manager's personal attention before he signs the final release note.

Steel Structure and Composition

A piece of normal steel consists chiefly of soft iron (ferrite) and a combination of iron and carbon crystals (carbide) in alternate plates of pure iron and carbide of iron. These striations or alternate plates under the microscope reflect the light waves and the combination is known as "pearlite." All mild steels considered microscopically consist of ferrite and pearlite, silicon, manganese, sulphur and phosphorus also being present. The relative areas occupied by the ferrite and pearlite depend on the amount of carbon, up to .9 per cent., when ferrite disappears as it has been absorbed by carbon to form pearlite. Any more carbon added after .9 per cent. exists as envelopes around pearlite and is called "cementite." Carbide of iron is hard and brittle, and therefore the more carbon

added, the more pearlite is formed and the harder the resulting steel. Toughness will decrease as soft iron becomes less, but toughness is good near one per cent. carbon content as hard carbide is cushioned between two plates of soft iron. When, however, the hard carbide is free to form large plates or brittle envelopes, separating grain from grain, the interangular cohesion is enormously weakened. High carbon steel is therefore used for turning tools, razors, scythes, where *no shocks* are to be withstood. Hammers, snaps, etc., must however be of low carbon steels for shock resisting. For aircraft steels it will be seen low carbon is universal, and although alloys, such as chromium, nickel, vanadium, etc., may be added, the fundamental basis is always soft iron and carbon.

Hardening

This is much too big a subject to deal with adequately in this lecture, but briefly if a piece of steel is heated to 700°C. and quenched in coldest water, it does not change in any way. If heated to 750°C. and quenched, it is much harder and under the microscope we see that the pearlite plates have diffused into one homogeneous mass and have been trapped by the sudden quenching before they have had time to return to pearlite and ferrite layers. This condition of diffused pearlite made permanent by sudden cooling is called martensite (after Martens, of the Berlin Test Labs., who first observed this after Sorby) and martensite is very hard. Now to allow this martensite to partially return to a softer state we temper the hardened steel and obtain softer troosite, sorbite, etc., and obtain the necessary wear-resisting hardness, combined with resistance to shock (toughness) so desired by the aircraft constructor.

Types of Steels

(*a*) The following carbon steels are used in aircraft :—

Specification 2 S.1, Pt. 2.—Medium carbon hot rolled bars.

Carbon, .28 to .40 per cent.
Max. stress, 35 tons per sq. in.
Yield point, 20 tons per sq. in.
Elongation, 20 per cent.

Is used for strut end sockets, bolts, eyebolts, solid forgings.

2 S.1, Pt. 1.—Bright bars.

Carbon, .15 to .45 per cent.
Max. stress, between 35 and 42 tons.
Elongation, 12 per cent.

Bend Test.—Bent double until sides parallel.

Plain Carbon Steels used for :—

Cylinders K.5
Combined forgings and stampings ... K.7

to get grain to flow round holding down lugs.

K.5 :—

Carbon, .35 to .45 per cent.
Manganese, not over .80 per cent.
Silicon, not over .25 per cent.

B.E.S.A. S.3 :—

Carbon, .25 per cent.
Manganese, .60 per cent.
Normalised after rolling, 830°—870°C.
Max. stress, 26 tons per sq. in.
Yield point, 18 tons minimum.

Fittings such as the following are usually made of the above steel:—

Wiring plates.
Fish plates.
Control fittings.
Spar sockets.
Control levers.

This steel is now being partially replaced by " Staybrite " on seaplane work.

N.B.—Foregoing carbon steels are not hardened and tempered as are alloy steels.

(*b*) *Case-hardening Steels.*

S.14. Carbon case-hardening steel, *i.e.*, a hard case produced on the surface of a soft steel by the ability of iron to absorb carbon at high temperature (900°). Initial carbon raised to 2 per cent. sometimes.

Carbon, .12 to .20 per cent.
Manganese, .5 to 1.0 per cent.
Core tests, 30 tons (max.) per sq. in.
Yield, 25 tons per sq. in.
Elongation, 20 per cent.

Parts such as engine valve cams and gudgeon pins.

N.B.—For a tougher core to support the case use 2—5 per cent. nickel or nickel-chrome case-hardening steel.

Core, 45 tons per sq. in.
Yield, 30 tons per sq. in.
Elongation, 15 per cent.

(*c*) *Alloy Steels.*

Now turning to alloy steels, there are roughly four general classes:—

(1) Chromium steels.
(2) Nickel steels.
(3) Chrome-nickel steels.
(4) Chrome-vanadium steels;

and these were produced to meet the demands of aircraft designers for steels to meet higher stresses than carbon steels could bear.

(1) *Chromium Steels.*

Chromium forms a carbide with carbon and has influence on hardness due to two causes, (1) mineral hardness imparted by hard chromium carbides, (2) chromium retards the change of the austenite and permits formation of a deeper martensite on hardening. Chromium appears to have the power of imparting hardness to great depth in large sections, giving penetration hardness. Chromium itself will not harden steel without presence of carbon. Chromium steels have fine grain when properly heat-treated; this means strong molecular cohesion, hence great toughness. Large crystals stand for weakness. Chromium increases the tensile strength and elastic limit without noticeable loss in ductility. For aircraft work this is very useful. For more highly stressed parts when S.1 Pt. 2 too weak.

Chromium, 1.00—1.25 per cent.
High carbon, .85 per cent.

Balls and races of wonderful strength and wear-resisting hardness on oil quenching. There is 2 to 20 per cent. of chromium in stainless and " Staybrite " steels, of which more later.

(2) *Nickel.* 2 to 5 per cent.

Heat treatment necessary to obtain maximum results. Nickel alloys with the soft iron and gives toughness and ductility.

S.15.—3 per cent. Nickel Case-hardening.
S.17.—5 per cent. Nickel C.H.

Propeller reducing gears are made from this steel, which withstands stresses of shear, wear, bending and shock, due to the hard case and tough core.

Gudgeon pins subject to shear, bending, wear, are also made from S.15 or S.17.

Nickel case-hardening steels do not permit of such rapid absorption of carbon as plain steels, but are not likely to be made brittle by long exposure to high carburising temperatures and they therefore withstand shocks better. The case is not quite so hard but there is a stronger core.

S.8.—3 per cent. Nickel Heat-treated Bars, for bolts, nuts, etc., fairly highly stressed.

S.4.—5 per cent. Nickel Sheet.
Carbon, .18/.24 per cent. Ni., 4.5/5.0 per cent.
Max. stress, 48 tons per sq. in.
Yield point, 70 per cent. of max. stress.
Harden at 820/860°C. and quench in oil.
Temper at 450/600°C. and cool in air or quenched.
Normalise at 820/860°C.

(3) *Chrome-Nickel.*

Nickel and chromium alloyed with plain carbon steel gives toughness and ductility from nickel and increased mineral hardness of cementite and pearlite from the chromium. This combination is most valuable for parts to be heat treated to develop great toughness and fatigue and wear-resisting properties.

S.2.—Nickel-chrome or vanadium hardened and tempered.
Carbon, .28/.34 per cent.
Nickel, 3 per cent. to 3.75 per cent.
Chromium, .5 to 1.0 per cent.
Max. stress, 55 to 65 tons per sq. in.
Yield, 45 tons per sq. in.
Elongation, 18 per cent.
Reduction of area, 55 per cent.
Izod, 40 ft. lbs.
} Hardened at 820/850°C. Oil-tempered at 560°C.

Used for cylinder holding down bolts and other highly stressed bolts.

S.11.—For crankshafts (torsion, bending and shock) and connecting rods (compression, tension, bending, shock).

S.33.—60-ton nickel-chrome.

S.28.—100-ton air-hardening steel. 790°C. to 830°C. and cool in air.
Carbon, 35 per cent. Ni., 3.75/4.75 per cent. Chrom., 1/1.8 per cent.
Used for propeller reducing gears.

(4) *Chrome-Vanadium Steel.*

Has become better recognised recently. Similar to chrome-nickel steels—supposed to be more easily machined and free from surface defects.

.30 per cent. Car. 1 per cent. Chrom. .20 per cent. V.
For great toughness and shock-resisting qualities.

.50 per cent. Car. 1 per cent. Chrom.
For springs.

Valve springs—hard-drawn chrome-vanadium wire.

(*d*) *Special Alloy Steels for Particular Purposes.*

(1) *High Tensile Nickel-Chromium Strip D.T.D.*54 (for spars, etc.).

Carbon, .25/.35 per cent.
Nickel, 3/3.75 per cent.
Chromium, .50/1.00 per cent.
Vanadium, .25 per cent.
Draws cleaner with vanadium.

Hardened 860°C. after forming in continuous electric furnace 2ft. per two mins. cooled in water-cooled dies. Tempered 300/400°C. in second furnace adjustable to width.

Tensile-proof stress not less than 65 tons per sq. in. (proof stress being defined as that stress at which the stress-strain curve departs by 0.1 per cent. of the gauge length from the straight line of proportionality).

As you are aware, any piece of steel commences to elongate immediately it is stressed. In designing statically stressed parts, the designer allows for a certain stretching of the material with a given load, hence a definite proof stress has to be carried by the test piece before it is stretched above a certain figure. The way the tests are carried out is by plotting on a curve the stretching effect to a steadily applied increasing load.

(2) *Non-Corrosive Steel Strip. D.T.D.45.*
Carbon, about .125 per cent. Cromium, about 13 per cent.
Hardened about 950°C. cooled air.
Tensile proof stress not less than 65 tons per sq. in.

(3) *"S.L.V." Cobalt Chrome for Valves.*

Silicon Chrome Heat-resisting Steel.

Carbon, .45 to .55 per cent.
Manganese, .40 to .60 per cent.
Silicon, 3.25 to 4.25 per cent.
Sulphur and phosphorus, .04 per cent. max.
Chromium, 8.00 to 8.50, but must not exceed 9 per cent.
Nickel, none preferable, but .5 per cent. max.

Cobalt Chrome Heat-resisting Steel for Valves.

Silicon, .96 per cent.
Manganese, .38 per cent.
Phosphorus, .04 per cent.
Sulphur, .02 per cent.
Carbon, 1.30 per cent.
Chromium, 11.19 per cent.
Cobalt, 3.05 per cent.

(4) *High Manganese Castings* for tail skids, to resist abrasion, cannot be machined or drilled, only ground. Contains 12 per cent. to 14 per cent. manganese, air hardens at 980°C.

Stainless Steels

High Chromium Steels.

Stainless steel was discovered in our laboratories prior to the war in a search for rifle and gun barrel steels to resist corrosion and erosion. First commercial use—cutlery. The war stopped domestic use and hundreds of tons were used for aero-engine valves, 12 per cent. to 14 per cent. chromium and .35 per cent. carbon.

Forms of Supply.—"F.H." in annealed condition for heat treatment by user (100 tons per sq. in.).
"F.G." in machinable bars to A.M. D.T.D.22A and B.E.S.A.62.
40/50 tons max.
Hardened 950°C. Tempered 650°C.

"F.M.," "F.I." to D.T.D. 21, 53.
Soft sheet and bar—low carbon—will not air-harden.

Castings.—Max., 45/50 tons. Yield, 20/25 tons. Elong., 15/18 per cent. Bend, 90°.

Scaling.—Up to 800°C. (1472°F.) hardly scales.

Ordinary mild steel seriously affected at visible red (500°C.).

Stainless steels can be soldered, brazed and electrically welded.

"Staybrite."

Chromium-nickel steel; 8/10 per cent. nickel, 18/20 per cent. chromium. Combines high resistance to corrosive influence with extreme malleability. It is ideal for aircraft fittings exposed to sea-water or moisture and is immune from corrosion attack, due to alternate wet and dry conditions, as on floats and boats.

"Staybrite" is non-magnetic in the soft state and cannot be hardened except by cold work. It is an austenitic like 14 per cent. manganese steel, *i.e.*, cannot be hardened, though it can be softened by quenching from high temperature (1250°C.).

Soft Sheets.

.20 per cent. Carbon. 6/10 per cent. Nickel. 16/20 per cent. Chromium.
Max., 54 tons per sq. in.
Yield, 12/15 tons per sq. in.
Elongation, 65 per cent. (elastic).

Hard Sheets by cold rolling.

Max., 55 tons per sq. in.
Yield, 35 tons per sq. in.
Elongation, 20 per cent.

"Staybrite" Castings.

Max., 35 tons per sq. in.
Yield, 15 tons per sq. in.
Elongation, 20 per cent.
Bend, 90°.

Bar Form. Higher Tensile (as rolled).

Max. not less than 50 tons per sq. in.
Yield not less than 22 tons per sq. in.
Elongation not less than 25 per cent.
Izod not less than 40 ft. lbs.

High Tensile Strip.—D.T.D.57.—Proof stress between 50 and 60 tons per sq. in. used for catenary links of new airship.

Riveting.—Small rivets can be done cold—if large, done hot.

Polishing.—Flour emery and swansdown buffs.

Machining and Drilling.—Machined, drilled and tapped with experience. Cold works rapidly, sharp tools therefore needed.

Resists nitric, wet and dry sea water, vinegar, citric acid, formic and lactic acid, phosphoric acid.

"Staybrite" in the soft condition can be cold pressed, bent, etc., into fittings without softening or further heat treatment. Hard sheets after bending may be heated to 400°C. to remove stress. Sheets are supplied descaled, *i.e.*, immersed in acid dip (50 per cent. hydrochloric, 5 per cent. nitric at 50°C. and suitable restrainer, rodine or picklette) and then carefully washed. Pickling removes rolling scale and leaves sheet with "silvery" finish which is rustless without polishing.

Welding, Soldering, Brazing

All operations performed satisfactorily. For electric and oxy-acetylene welding use " Staybrite " electrode or filler with a reducing flame and low pressure in the case of axy-acetylene; clean the weld with pickling mixture and wash.

TABLE I.

ANALYSIS TREATMENT AND TESTS ON VARIOUS CARBON STEELS.

		0.15 per cent. carbon.	30-ton carbon.	40-ton carbon.	50-ton carbon.	0.9-1.0 per cent. carbon.
Carbon, per cent.		0.15	0.31	0.45	0.60	0.90
Manganese, per cent.		0.30	0.67	0.70	0.69	0.55
Silicon, per cent.		0.06	0.14	0.15	0.20	0.11
Sulphur, per cent.		0.034	0.048	0.044	0.04	0.036
Phosphorus, per cent.		0.018	0.04	0.036	0.039	0.031
Chromium, per cent.		Nil	Nil	Nil	Nil	Nil
Nickel, per cent.		Nil	Nil	Nil	Nil	Nil
Condition.		Normalised 900°C.	Normalised 850°C.	Normalised 820°C.	Normalised 810°C.	Normalised 850°C.
Tensile.	Elastic Limit, tons per sq. in.	14.0	20.05	21.5	27.0	23.16
	Yield point, tons per sq. in.	14.0	20.70	22.9	29.16	32.4
	Maximum Stress, tons per sq. in.	21.4	35.17	41.2	48.60	59.4
	Elongation, per cent.	45.0	30.5	25.0	22.0	11.0
	Red. of Area, per cent.	73.56	54.6	47.0	37.9	15.5
Torsion.	Yield	7.63	14.1	15.6	16.6	18.8
	Probable Max. Stress	20.95	27.51	29.0	33.3	35.7
	Degrees Twist	1070	548	434	320	184
Izod, ft. lb.		81	33	28	8	2
Arnold, Reversals		456	444	500	480	352
Stanton, Blows		1016	1413	1244	1139	264
Sankey, ft. lb.		2300	1700	3974	2496	1112
Brinell No.		95	156	170	223	286
Shore No.		21	27	29	35	40

WATER-COOLED AERO ENGINES

Lecture read before the Yeovil Branch on November 18th, 1927.

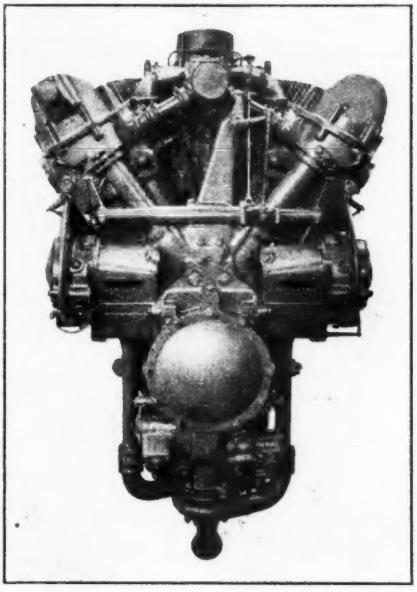
BY A. A. RUBBRA, B.SC., OF ROLLS-ROYCE, LTD., DERBY.

It is the author's intention in this paper to deal with water-cooled engines in a general way, passing on to a consideration of the developments of this type of engine, and constructional details.

Both air and water-cooled engines have been used since the early days of flying, and as each has its own particular field wherein it is more suitable, both types will probably continue to be used in the future.

The requirements of an aero engine vary with the use to which the engine will be put in service, but speaking generally, it may be taken that the chief requirements are:—

1. Low weight per thrust horsepower.
2. Maximum efficiency
3. Reliability.

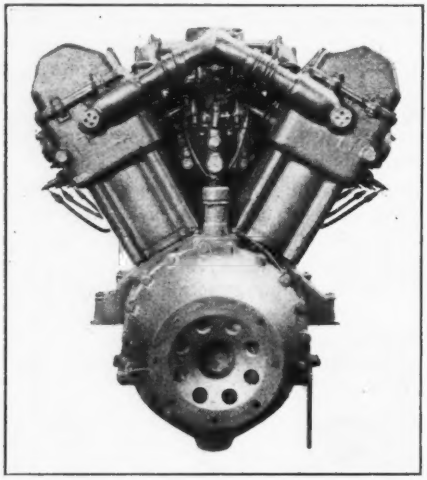


Rolls-Royce "F.10" Aero Engine.

Power and Weight

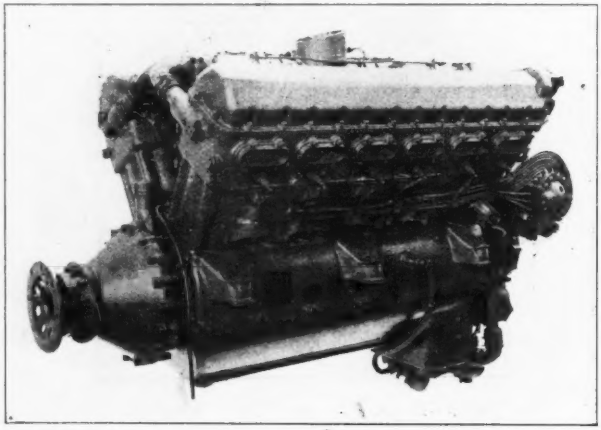
The usual weight comparison basis is the weight per b.h.p. at the airscrew shaft. This, however, puts the engine with a reduction gear at a disadvantage, owing to the additional weight entailed, and a fairer comparison would be the weight per thrust horsepower. This quantity is difficult to measure, and this explains why the former factor is generally quoted.

The dry weight of a water-cooled engine can generally be made less than that of an air-cooled engine for the same power, but when the radiator and water are taken into account, the total power plant weight is somewhat greater.



Rolls-Royce "F.10" Aero Engine.

The fuel and oil consumption of the water-cooled engine are, however, less than those of the air-cooled engine, and this becomes of increasing importance as the flight range of the machine in which the engine is installed increases.



Rolls-Royce "F.10" Aero Engine.

From average figures, for a machine weighing 15lbs. per b.h.p., the increase in power required for propulsion is 27 per cent. for an increase in consumption of 1lb. of fuel per b.h.p. hour, over an eight-hour flight period.*

* Aeronautical Journal, August, 1922.

Apart from this, low fuel and oil consumptions in terms of thrust horse-power are of prime importance on commercial lines.

The fuel consumption of the water-cooled engine is approximately .47lbs. per b.h.p. with the highest compression ratios that will permit full throttle running on the ground with standard fuels. By slightly increasing the compression ratio and running the engine either permanently throttled or throttled to a rate below a certain altitude this figure can be still further improved.

Speaking generally, it is possible to obtain slightly higher mean effective pressures on the water-cooled engine than on the air-cooled, for the same cylinder dimensions, owing to the elimination of hot spots in the combustion head.

The power obtainable from a fixed radial engine is seriously limited by the speed at which the crankshaft can be run, owing to the high inertia loading on the single big end. The greatest advance made in power production in water-

"Condor" Series III.
Piston and Connecting Rods.

cooled engines, apart from supercharging, has been in the direction of increased revolutions per minute. 3,000 r.p.m. on a 500 h.p. engine is now not uncommon, and while this does not sound extraordinary in view of the speeds obtained on modern racing car engines, yet when we come to compare piston speeds, this rate of revolution is truly terrific. By making the crankcase and rotating parts very stiff and increasing the oil flow through the bearings, it has been possible to increase the loading factor on the bearings to an unbelievable extent, as shown in Mr. Laurence's recent paper before the Institution of Automobile Engineers.*

The crankcase, crankshaft and big ends of recent Rolls-Royce engines furnish a striking example of how the requisite stiffness is obtained in these parts.

The main bearings, which are of white metal in steel shells, are carried in block forgings of light alloy built into the crankcase, the whole being braced by through bolts both horizontally and vertically.

* Proc. I.A.E., Vol. XX., p. 340.

The connecting rod big ends are of forked construction, the blade rod working on the outside of the bearing shell attached to the main rod. The bearing shell is white-metalled directly on to the steel both inside and outside. This type of construction was first successfully used on Rolls-Royce engines and has several advantages over the articulated type, owing to improved balance, increased strength, and reduced piston side thrust.

There is a tendency on both air and water-cooled engines to reduce the connecting rod length, as this has a direct influence on the frontal area of the engine as a whole. The minimum connecting rod length possible is fixed by the extent to which the piston side thrust may be increased, and for this reason the forked construction has definite advantages. On air-cooled radial engines the articulated type of big end is the only one possible, and it is this that sets the limit to the minimum overall diameter of the engine.

Westland Yeovil Bomber—Rolls-Royce "Condor" Engine.

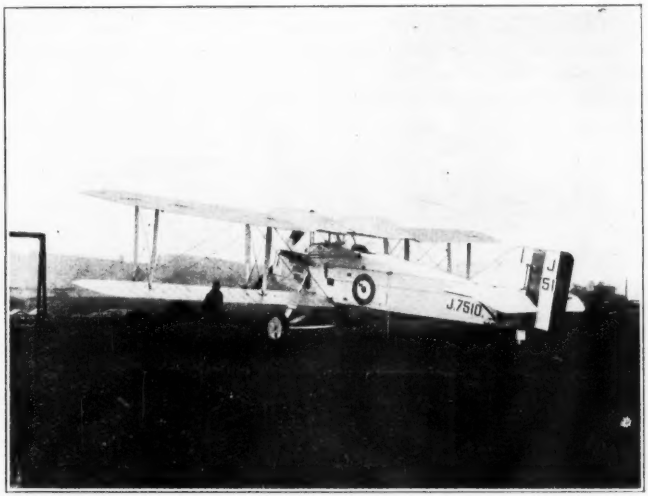
It is also possible on high speed engines to use compression ratios undreamt of two or three years ago, owing to the lower mean effective pressures at which the high speed engine can be run and to the increased inertia forces which tend to cancel the higher explosion loadings. This means a further substantial gain in economy over that already obtained by the water-cooled engine as compared with the air-cooled.

Turning to the question of the efficient conversion of engine b.h.p. into thrust horse-power, the frontal area presented by the engine behind the airscrew is of paramount importance, and it is here that the water-cooled engine scores heavily over the air-cooled radial. From this point of view, the Vee type of cylinder arrangement, as exemplified by Rolls-Royce practice, is better than the broad arrow construction. It is also important not only to reduce the frontal area to the minimum possible, but to provide clean, smooth lines, and great strides are being made in this direction, as shown by the new F. engine. We hope to be able to produce eventually an engine that will do away with the need of cowling almost entirely, thus saving weight and improving the accessibility of the engine when installed.

The small frontal area of the Vee type water-cooled engine also gives improved vision for the pilot on single-engined machines.

Reduction Gears

The best speed at which to run the airscrew varies with the speed of the machine in which the engine is installed, but in most cases it is found advisable to fit a reduction gear between engine and airscrew, as even in racing machines the engine speed is much higher than the best airscrew speed. For racing machines the air-cooled radial engine is at a disadvantage because the overhaul diameter of the engine is very large compared with the diameter of the airscrew, and also the engine cannot be run fast enough to warrant the addition of a reduction gear.



Westland Yeovil Bomber—Rolls-Royce "Condor" Engine.

If two otherwise similar engines be made with and without reduction gears, then for the same power plant weight, the engine without the reduction gear can be made roughly 10 per cent. larger. The additional power obtained from the larger engine is, however, almost entirely offset by the reduced airscrew efficiency, and, further, requires fuel and cooling in proportion to the increased capacity.

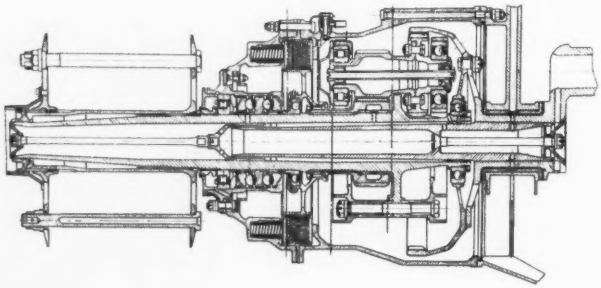
Reduction gears have always been a feature of Rolls-Royce engines. The earlier ones were of the epicyclic type, and this gear has several advantages over the plain spur type, one being that it puts much less strain on the front end of the crankcase, and in some cases, on the engine bearers. One other rather important point is that it is comparatively easy to convert the epicyclic gear into a two-speed reduction gear without adding seriously either to weight or complication. With a two-speed gear it is possible to obtain greatly improved take-off and climb, and also better fuel economy when cruising. In fact, the two-speed gear gives most of the advantages of the variable pitch propeller, about which we have heard so much, in a very simple and practical way.

The plain spur gear can be made somewhat lighter than the epicyclic, and with this type the airscrew centre line can be moved up to the centre of area

of the engine, at the same time increasing the ground clearance of the airscrew. A reduction gear of this type adds only about .2lbs. per b.h.p. to the weight of the engine. The efficiency of the gearing is very high, and on the test bed we have never been able to detect any difference in the power between geared and ungeared engines of otherwise similar type. We conclude from this that the efficiency is certainly not less than 98 per cent., and is probably somewhat higher than this.

Auxiliaries

In order to obtain uniform torque at the reduction gear it is necessary to have not less than twelve cylinders, and with the Vee type engine this entails a rather long crankshaft. In spite of the stiffness with which this member is made, a certain amount of torsional flexure is inevitable at the rear end of the shaft, and for this reason the drive to camshafts, magnetos, and the rest of the auxiliaries is of the damped spring coupling type on all Rolls-Royce engines. This results in a greater length of life of all parts concerned, and an increased reliability. In addition to this drive, the magnetos are driven by further damped spring couplings from a secondary shaft.



R-R.E. IX.
Epicyclic Reduction Gear.

On water-cooled engines it is possible to enclose the whole of the camshafts and valve gear, as on the new Rolls-Royce F. engine, ensuring an adequate lubrication of these parts, and also improving the lines of the engine. With air-cooled radial engines it is difficult to do this without adding seriously to the weight of the engine and also interfering with the cooling of the cylinder head.

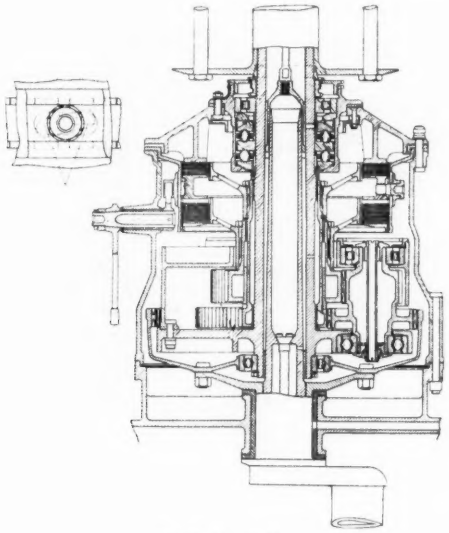
Cooling System

Turning to the cooling system, the brake thermal efficiency of the water-cooled engine is very high, the amount of heat to be got rid of being on the average 22 B.Th.U's per minute per b.h.p. The working temperature of the water-cooled engine is more under control than on the air-cooled, so that the engine may be run under the best temperature conditions all the time, whatever the atmospheric conditions may be. Jacketting of the mixture pipes and carburettors is also a simple propositon, and this is important in view of the freezing up troubles experienced with the carburettors on air-cooled engines during long drives. Jacketting also gives improved distribution of mixture to the cylinders, and even slow running.

Circulation of the water in the cooling system is invariably by means of a centrifugal pump, and the rate of circulation is generally in the neighbourhood of 15 gallons per minute per 100 b.h.p., with a total resistance in the external water circuit of 6lbs. per square inch.

Engine Suspension

With regard to engine suspension, the bearers should be arranged to take the torque reaction as near to the airscrew as possible. On the Rolls-Royce "Condor" engine a three-point suspension is used, which not only prevents the crankcase from being stressed due to the flexing of the whole suspension, but also puts much less strain on the bearers themselves.



R-R.E. XV.
Two-Speed Epicyclic Reduction Gear.

Controls

In order to simplify the engine controls as much as possible, the magneto control is often coupled to the throttle control, so that the magnetos are fully retarded at small throttle, and fully advanced with the throttle about three-quarters fully open. This ensures maximum combustion efficiency at cruising speeds and prevents the engine being run slowly with advanced ignition. The altitude control is also interconnected with the throttle, so arranged that closing of the throttle returns the altitude control to the full strong position. With this scheme it is impossible for the pilot to open up with a mixture too weak to run the engine, after a long dive.

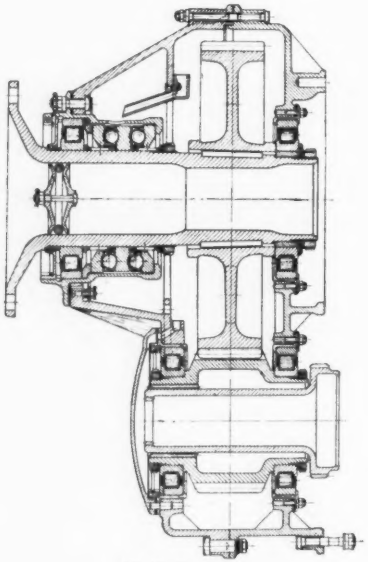
Petrol System

Gravity feed to the carburettor appears to be the most reliable system in use at the present time, owing to its inherent simplicity. This is difficult to arrange on some machines, however, and satisfactory engine-driven pumps are now being evolved, which, by incorporating a relief valve, enable the carburettor to be fed direct from the pump.

The pumps fitted to Rolls-Royce engines are of the simple gear type. A gland and an oil seal are provided on the pump spindle to prevent petrol leaking into the engine crankcase, and a further precaution is taken in providing the gland with a drain external to the engine. A small quantity of oil is allowed to leak into the pump gears, ensuring freedom from seizure, and enabling the pump to start work without priming, even when the main tank is situated a considerable distance below the engine.

Starting Systems

There are several starting systems at present being used successfully. One is the well-known Bristol gas starter, in which compressed mixture is supplied by a donkey engine, and distributed to the engine cylinders in the correct firing order.



R-R.C. III.
Spur Reduction Gear.

Hand turning gears are also being used in conjunction with a priming device, and a starting magneto. On the Rolls-Royce hand-starter the reduction from the hand turning shaft to the engine crankshaft is by an irreversible worm, while the worm gear itself is provided with a slipping clutch, so that the operator is fully safeguarded against injury in the event of a backfire.

Of all the systems, the Hucks is probably the simplest from the engine designer's point of view.

Supercharging

Both the exhaust-driven and the gear-driven types of supercharger are being developed on water-cooled engines. With regard to exhaust-driven superchargers, the manifolding can be made much more simple than with air-cooled radial engines, and the blower unit can also be installed where it will have very little effect on the frontal area of the engine, and where the turbo portion and intercooler will receive maximum cooling. The exhaust-driven blower will

probably continue to be used where it is required to maintain normal engine power up to very high altitudes. Compared with the geared blower, it adds considerably more weight to the engine, and also has other disadvantages, such as burning of manifolds and exhaust valves, and difficulties in connection with the airscrew.

The gear-driven blower is making good progress, but only flight tests will show what is the best amount of supercharging to employ. At the present, with fixed airscrews and direct drive or single step reduction gear, the best policy appears to be to arrange for a very moderate degree of supercharging, say maintaining ground level power up to 6,000 ft. The moderate supercharger takes very little power to drive it, and enables a considerable degree of boosting to be used at ground level with standard fuels, owing to the lower temperature of the compressed charge, giving considerably improved take-off and climb. The moderate supercharged engine also requires very little more radiator surface than the normal engine, while the fuel consumption is generally about the same, owing to the improved distribution and the reduced pumping losses. With a variable pitch propeller or a two-speed reduction gear, it should be possible to supercharge to a greater extent without overloading the engine on the ground.

LEEDS BRANCH

Opening Meeting at Leeds University, November 10th, 1927

Professor W. T. DAVID, who presided, said this was the first meeting of the Branch, and, having been elected Chairman, he wanted to say that anything he could do for the success of the Society would be done. They wanted as many people to join as possible. There were no technical qualifications required beyond the fact of general interest in aeronautics. A very interesting series of lectures had been arranged, and he would like to point out to engineers that it would be to their advantage to join the Society because the development of aeroplane manufacture would react favourably, he hoped, upon the engineering industry. That was something very much to be desired. The Yorkshire Aeroplane Club had offered students who joined the Society membership of the Club on advantageous terms.

Sir SEFTON BRANCKER said although he was President of the Royal Aeronautical Society he was in no sense a scientist or technical expert. He would indicate the sort of scientific problems that were arising and what was being done to meet them. Air transport had been going as a commercial proposition for eight years, and from very small beginnings it had attained a very remarkable volume of traffic throughout the world. Three years ago there were 13,700 miles of organised air routes in Europe. During the year 6,110,000 miles were flown. For 1927 the figures so far were 53,500 and 16,920,000. Unfortunately, we had taken a very small part in it. Great Britain had 1,350 miles of organised air routes and 840,000 miles were flown. Australia had the best example in the Empire with 3,300 miles of routes and last year nearly half a million miles were flown. Australia would probably more than double her mileage next year.

The leading nations in air transport were France, Germany, America, Belgium and Great Britain. Nearly every other country in Europe was endeavouring to develop its own national air service. The policy of the French Government after the war was to subsidise air transport heavily. Her chief object was quicker communication with her overseas possessions and also to form immediately a military reserve. The last thing she thought about was making it a commercial proposition.

Sir Sefton illustrated with lantern slides the extent of the French air routes throughout Europe, to French Syria, West Africa and other places. The Latacoer mail service had been a great success, six million letters having been carried in 1926. Italy was only just starting, but her service was extremely efficient. The star turn in Europe, he said, was Germany. She flew over four million miles last year and had a most elaborate, skilfully organised and linked-up system of air transport within the country. There was a daily service from Berlin to Moscow, and it was hoped to extend this across the continent to Pekin. Germany was the only nation in Europe to run a night service satisfactorily, and outside Germany she was extending her influence a great deal. In America many companies were operating and a real commercial effort was being made. Some time ago a Post Office route was started from New York to San Francisco, a distance of 2,500 miles, which was covered in thirty hours. Nineteen companies were operating and some appeared to be going very strongly. In one or two cases they were making money without a subsidy. Belgium was doing little at home and was spending her money in the Congo. She was planning a route to Lake Albert to join up with our service from Cairo and offered to extend southward towards the South African Dominion. Here again the Government gave substantial assistance. Holland had made a very good beginning and, apart from services to Sweden, Paris and London, a scheme for a weekly mail service to the Dutch East Indies was under discussion.

The speaker proceeded to refer to the International Convention of Air Navigation which set down principles concerning ownership of the air and freedom of innocent passage, but it gave every country power to dictate the line of air route across its country. It called for the provision of customs landing places, etc. At present there was a good deal of suspicion and jealousy as indicated by the Persian obstruction and Mussolini's declaration. On the other hand, there were several attempts at international co-operation. The Germans, Italians and Austrians had got together and were running a joint service. Germany, Austria and Czecho-Slovakia were running a service from Berlin to Prague and Vienna. He thought we should see air transport grow up on much the same lines as the mercantile marine grew up in the past. Countries would provide the best possible air ports and try to induce foreign aircraft to enter those ports.

These services were running with remarkable regularity and safety. The standard of safety was really very high and people did not realise it. From experience he knew that they ran like trains in many parts of Europe. France admitted three deaths per hundred thousand hours or eight million miles of flying. Germany had had two in the last year. We had had none since Christmas, 1924. We had a service from Cairo across the desert to Baghdad and Basra. It was intended that we should go to India, but we were held up by Persia. We had beaten the world, for during ten months we had maintained 100 per cent. regularity. Australia had a very good weekly service up the west coast and other regular services, and now she was contemplating coming up the Dutch East Indies to Singapore and India.

Since 1919 we had had only fourteen accidents involving the death of a passenger and during that time six million miles had been flown. Since 1924 there had been none at all. If one examined the causes of these accidents one found that in eight cases out of the fourteen it was due to an error of judgment, and in nearly all to loss of speed on a turn. Mr. Handley Page's latest invention of an automatic slot would enable pilots to land very slowly and to turn with greater safety, and he thought most of the accidents referred to would not occur again. Despite these standards of reliability and safety the services could not pay their way. There were a few exceptions, but the reason was twofold :—

High cost of operation, and
Lack of support by the public.

The problem, then, was to beat down the first and push up the patronage of the public. The outstanding items in the cost of operation were the cost of fuel and oil, maintenance and equipment, and the amount of work done by each unit of the fleet. In the matter of insurance great reductions had been made. Immediately after the war they were charged something like 20 to 25 per cent. on the capital cost of each aircraft per annum. Now the figure was $7\frac{1}{2}$ per cent. and would come down still more.

Economies of fuel had been thoroughly tackled. What was wanted was an air-cooled heavy oil engine. With a heavy oil engine a saving of 20 per cent. in weight and 75 per cent. in cost of fuel could be made, and he believed it possible during the next two or three years to place a great many air transport services on a paying basis.

Intensive use of aircraft was a factor of great importance and the extension of night flying would reduce overhead charges. Progress was being made in reducing costs of operation. Engine maintenance and aircraft maintenance had been reduced. Aircraft were now doing twice as much work between overhauls as before and he hoped to reach eventually four hundred hours' flying between overhauls. The greatest enemy to-day was valve trouble.

The next development he looked for was an all-metal monoplane instead of the biplane, by which they would save in maintenance and structural weight. Reduction of the structural weight added a corresponding amount to the pay load. Professor Jones had been going into the value of streamlining and had come to the conclusion that at speeds we were going at a third of our present power would be sufficient if proper streamlining could be produced. Two-thirds of our available power was wasted. From the point of view of air transport speed was of the utmost importance. To-day, 100 miles an hour was looked upon as an economical speed. In working out a proposed route of 2,500 miles there was a difference of nearly £8,000 a year between 90 and 100 miles per hour. The saving came in fuel maintenance, wireless fees and flying pay of the crew.

Mr. Handley Page suggested a folding undercarriage, enclosed pilot and crew, a geared engine, and claimed that eventually aircraft would weigh 25 lbs. to h.p., of which only seven lbs. would be structural weight of the aircraft itself. These machines with 250 h.p. would carry a similar load to that carried by 700 h.p. machines now. Mr. Handley Page might be optimistic, but it indicated the sort of progress which could be made through the growth of research and technical development. As indicating the progress that had been made, Sir Sefton Brancker said in 1915 he was at the War Office and a statement was received from the Expeditionary Force asking for a two-seater capable of running 90 m.p.h. for four hours, or at 80 m.p.h. for six hours; another to do 120 or 100 m.p.h. for four hours; a single-seater to do the same for six hours; a single-seater to carry 550 lbs. of bombs at 80 m.p.h. for six hours. These demands were looked upon as exorbitant and experts said the second and fourth could not be done. Yet the requirements were fulfilled within a year.

Steady progress was being made with existing aircraft. Flying costs were being reduced as shown by the following table:—

Single machine	1922	4/2	ton-mile.
Twin	1922	3/2½	,,
Twin	1926	2/10	,,
Triple engine	1926	1/10	,,

This pointed to big aircraft in the future and Germany was experimenting with a machine with ten engines. He thought five was the limit and would rather see three. He saw no reason why we should not get down to 1/- a ton-mile operating costs. On the subject of reliability in Europe difficult weather conditions had to be encountered, but the reliability last year was just about 92 per

cent. So far this year it was 96 per cent., partly due to three-engine machines, to greater stability, and to better weather reporting and wireless. Greater reliability would come with stabilising devices, more perfect engines, and fog landing devices. Developments were already well advanced with the last-named.

Patronage by the public was going up and goods traffic was increasing steadily. Imperial Airways reported an increase of 6.47 per cent. of passengers and 50 per cent. in special charters. Germany admitted 70 per cent. of subsidy to 30 per cent. of revenue. We were about 50/50. On the other hand, last year two American companies made a profit apart from any assistance. In the British Empire we had greater distances to cover, but it was very difficult to educate the public to any new idea. Money was wanted for ground organisation and the development of better commercial aircraft. A good deal of criticism had been directed against the Government, whose function, it was said, was not to develop commercial aircraft, but the Government had come to the conclusion that it was probably best to spend the money in this way. So long as the Government did it, the information was at the disposal of everybody. We wanted :—

All-metal construction and lighter material.
Cleaner design with ease of maintenance.
Lower fuel consumption per h.p., heavy oil, stabilising devices, and fog landing signals.

We could achieve these things better than anyone else if we exerted ourselves, as witness the successes in the Schneider Cup and the Jupiter engine on the Cairo-Basra route.

Replying to questions, Sir Sefton said properly maintained an aeroplane did not seem to grow old. Defective parts were absolutely renewed. Obsolescence was the real ranger. Planes lasted six years and possibly longer. For a heavy oil engine he suggested a horse-power of 400/500. As soon as civil aviation came on to a paying basis there would be a tremendous boom, for every nation wanted quicker communication. Germany wanted to be the first in the aircraft market when the boom came. She was not allowed to have an air fleet, but would be able to have far greater reserves with this highly developed civil aviation service.

Sir Edward Brotherton, President of the Yorkshire Aeroplane Club, said aerial transport would become a great commercial and industrial service. Transport was one of the most important undertakings. Unless we had the right transport we could not advance as an industrial nation. He did not know anything which was more attractive than anything connected with an aeroplane, which intimately concerned science, discovery and mechanical possibilities.

Colonel Kitson Clark emphasised the romantic side. While they had listened, he said, to a masterly analysis, there was behind it a great spirit of adventure which certainly appealed to Englishmen. He asked if atmospheric conditions favoured some nations in the matter of aviation development.

Sir Sefton said the only form of atmospheric condition which really hindered aviation was bad visibility, and we experienced that in this country. The other disadvantage was that whereas our island situation had made us a great seafaring nation, it reduced our incentive to fly. In the United States, Russia and Germany there was an enormous incentive to fly. On the other hand, we had a great Empire and if we thought in terms of Empire we should be all right.

REVIEWS

Aerodynamics

Edward P. Warner, A.B., M.S. McGraw-Hill Book Company.

"The Aerodynamics of Aeroplane Design" would have been a truer title for this book than the more comprehensive one given. It exactly fills a niche in the world of aeronautical literature which has always been empty. It is a predigested summary of published knowledge of the subject of its title, presented in such a manner that it is directly applicable to aeroplane design. It is not in any sense a rival to such books as Bairstow's "Applied Aerodynamics," but rather is auxiliary to them, in that it devotes most of its matter to bald statements of facts in Part I., the general theory, and straightforward explanations of the application of that theory in Parts II. and III., performance estimation and control and stability respectively.

The author claims that he has written it primarily for students of aircraft design and as such it can be confidently recommended. Certain "Americanisms," which are principally in the nomenclature used, are fully explained in the opening chapter and their English equivalents given, but these are not so prevalent as to make the book as unreadable as some American publications. Incidentally, in what respect is "Stagger Wires" an improvement, logically, upon the original English term "Incidence Bracing"?

The only real fault in a book claimed to be written for beginners is the lack of examples, either worked out in the text or as exercises at the end of each chapter. It is almost inconceivable that a professional teacher should not have realised how essential is the working out of illustrative exercises, in that it brings home to the reader those points which he has not fully appreciated or understood.

F. T. H.

Basic Principles of Air Warfare

By Squadron-Leader. Gale and Polden, 7/6 net.

In this book Squadron Leader has made a very commendable effort to do nothing less than unravel, for his own satisfaction and for the enlightenment of his readers, the confused threads of our present policies of National and Imperial Defence.

I have read every word, and have done my best to follow the workings of the Author's mind, for if one can only get at the spirit behind the written word it is possible, at once, to establish a sympathy. I feel certain that, if this is Squadron Leader's first attempt to solve problems which puzzle him, and which are puzzling many serious students of National and Imperial affairs, he will be impelled later to write further on the matter.

The book is written from the point of view of an Air Officer, but it is not biassed—it presents no arguments which are in any way unbalanced as between the claims of the three Fighting Services. The Author insists again and again—and with the utmost emphasis—upon the necessity of "Co-operation" between these Services. May I suggest to him that it is *absolutely impossible* to get effective co-operation—so long as there is "Division of Responsibility." There is no getting away from that fact—it is fundamental.

The Author should devote more time to a study of the details of the problems which face the Navy. He says: "During the war, the comparative ineffectiveness of the torpedo against battleships was proved beyond doubt." That

could only have been written by a man who did not know how battleships were built, and had not troubled or had opportunity to study their weaknesses. The statement is quite incorrect—it is not even remotely true. Nor does the Author reach sound conclusions as to the probable development of aircraft attack against ships. When Squadron Leader understands the reality of the menace now to be faced by surface vessels of all kinds, he will find it necessary to rewrite much of this book.

Squadron Leader obviously feels a repugnance towards the idea of deliberately attacking civilians, and, even if somewhat half-heartedly, pleads that the making of such attacks is wrong in principle. To my mind it is to be condemned, not only as being altogether barbarous, but as being dead against sound military teaching. Whatever may be urged by men who advocate the wholesale attacking of civilian centres, with the deliberate intent of wiping out the non-combatant populations in those centres—who is going to carry out this infamous task? Is Squadron Leader prepared to drop gas bombs or to spray gas over densely populated districts? From a close study of his book, I believe not.

He certainly does say, referring to such attacks:—" It is, however, a subject to which attention must be given by those responsible for the country's security. It is essential not only that we are prepared to meet any such attack and to minimise its effect, but also, so long as such a form of warfare is possible, to ensure that we ourselves are equipped with similar and even more efficient means to be employed against an unscrupulous foe."

But I cannot believe that an author who so thoroughly appreciates the fundamental principles of warfare, and who continually reiterates that basic truth that " the surest and quickest method of winning a war is to defeat the armed forces of the enemy," would be so foolish as to waste time and material on merely retaliatory measures, even though they be advocated by men who pride themselves on their " air-mindedness."

I was asked to review this book. Well, books are of no use unless people read them and talk about them. We, none of us, are satisfied with the present state of our National and Imperial Defence schemes. The Army, the Navy, the Air Force, and the Non-combatant are alike puzzled and worried about the future. Such books as Squadron Leader's deserve attention—they *demand* attention.

How are they to get it? May I again sincerely commend to the Councils of Technical Societies the idea that they should go out of their way to arrange evenings for the discussion of the vital matters raised in books of this type.

Squadron Leader asks for—insists upon—" Co-operation." I hold that it is impossible to ensure " Co-operation " if there is " Division of Responsibility." Neither Army, Navy nor Air Force is willing to budge an inch from its entrenchments.

Are Non-combatants content to leave it so?

E. F. SPANNER.